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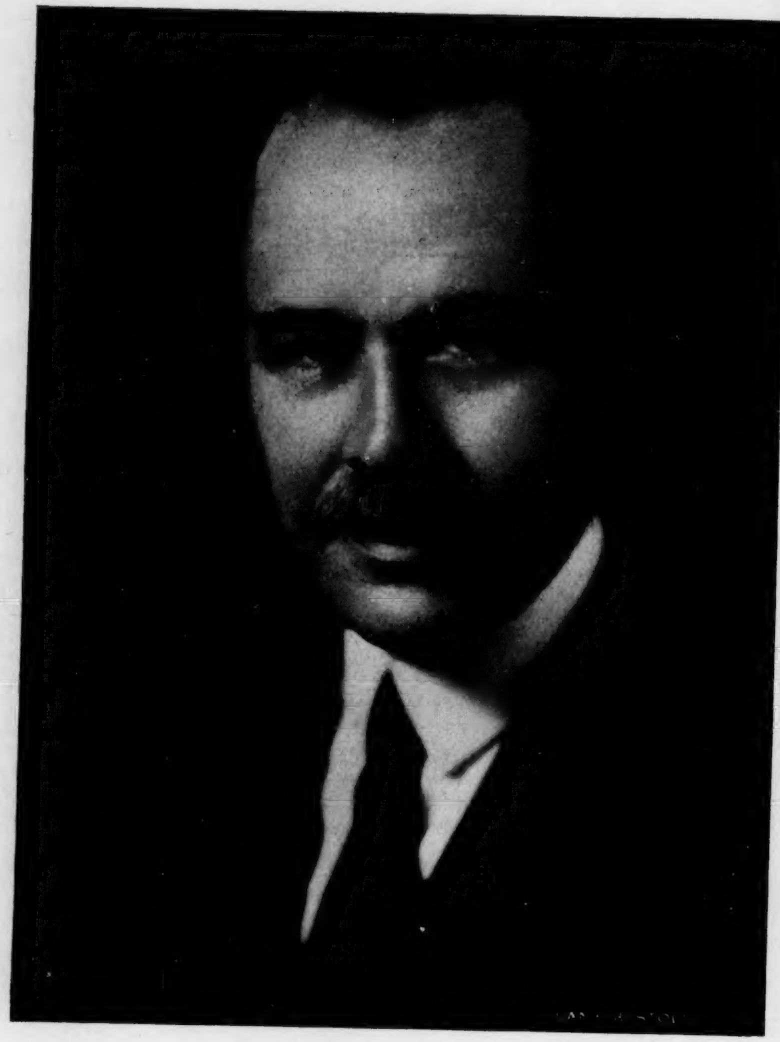

MALCOLM PIRNIE, PRESIDENT, 1933–1934

# JOURNAL

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**The Association is not responsible, as a body, for the facts and opinions advanced in any of the papers or discussions published in its proceedings**
***Discussion of all papers is invited***

Vol. 25 JUNE, 1933 No. 6

## THE NEW AUXILIARY WATER PLANT AT ERIE, PA.

BY J. T. CAMPBELL

*(Of the J. N. Chester Engineers, Pittsburgh, Pa.)*

The city of Erie, Pa., has two complete water works plants. The original plant at the foot of Chestnut Street was built in 1912 and has a capacity of 37 million gallons per day, the intake being the limiting feature. In 1929, the consumption of water nearly reached the maximum capacity of this plant and a new plant became a necessity.

The construction of the new plant, now known as the West Filtration Plant, was begun with the letting of the intake contract in November, 1929 and completed in February, 1932. The plant has a capacity of 16, and is capable of being extended to 72 m.g.d., or the capacity of the new intake line.

### INTAKE

The intake consists of a 72-inch riveted steel line approximately 8800 feet long, laid from the new low service pump station on the shore of the bay at Tracy Point, extending across the bay, through the peninsula, and thence beneath the lake bottom to a point 6000 feet north of the western extremity of the peninsula where it terminates in in a wooden crib 40 feet square by 17 feet 6 inches deep. The top of this crib is set 6 feet above the lake bottom and has 25 feet of water overhead at mean lake level. Across the bay and the peninsula, the

intake line was laid in the dry, trench being sheeted and diked to keep out the water of the bay. Rock was encountered in these sections of the intake trench and the progress of the work was very slow and laborious. That portion of the intake line in the lake beyond the peninsula was laid in the sand and sandy clay material, and the excavation was made by dredges. A sub-marine joint was used to joint the line, connections being made with divers.

The crib itself was of timber construction divided into nine pockets approximately 12 feet square. The four corner pockets were filled with rock to sink the crib and hold it in place. The intake manifold consisting of riveted steep pipe with openings in the same is located in the crib, the inlets being located in three of the pockets. The manifold is carried directly through the crib and bulkheaded on the outside with a blind flange to provide for future extension of the intake; should the necessity ever arise for carrying the intake further out into the lake on account of contamination. The inlets into the manifold contain coarse bar gratings across the openings. These, however, are located four feet below the top of the crib. The top of the crib above the manifold openings is covered with a wooden grating composed of two by ten white oak timbers securely fastened together, set on edge with a two inch space between. The space around the crib is covered with stone sloping from the top of the crib to the lake surface on an approximately 3:1 slope, this riprap affording protection to the crib against storms and other possible damage.

## LOW SERVICE PUMP STATION

The water flows by gravity through the intake line into a wet well located below the floor of the low service pump station. This well is 107 feet long by 22 feet 6 inches wide, and has a depth of 23.5 feet below the floor level. The low service pump station is a stone structure housing one 16, two 8 and one 2 m.g.d. motor driven centrifugal pumps. These pumps take their suction lirectly from the wet well below and discharge through the two cast iron lines to the main filter plant located approximately 1200 feet to the south on a flat plateau overlooking the bay. The station itself has been made large enough to house pumps to the capacity of the intake, and no alterations, other than the cutting of holes through the floor, will be necessary for future extension. The pumping units in the low service station are operated by remote control from the high service pump station in the following manner. A push button on the control table

located on the balcony of the high service pump station throws into operation a vacuum pump in the low service pump room, thereby priming the low service pump. The resulting vacuum is recorded on a dial in front of the operator and when the pump has been primed it is automatically thrown into service, and the vacuum pump shuts down. The operator, at his table, notes on his ammeter the increased flow of current which advises him that his vacuum pump is running and the further increase when the low service pump throws in. He

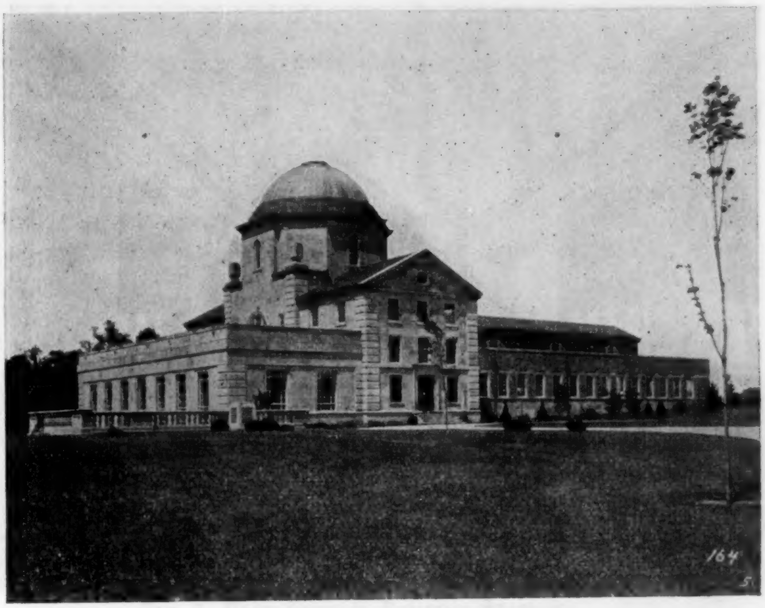

FIG. 1. OUTSIDE VIEW OF THE HIGH SERVICE PUMP STATION, COAGULANT HOUSE AND FILTER BUILDING

can also, from his position, see the venturi meter indicator located on the floor of the high service pump station which tells him that water is being pumped into the mixing chambers. Signal lights on the board indicate which pumps are running, and he is further provided with an ampliphone which permits him to listen in to the operation and he can tell, from the various sounds, when the vacuum pump starts, when it stops; when the low service pump starts, and whether everything is working successfully. Further protection is afforded to the pumps by automatic devices for closing down the pumps or

motors in case the bearings are running hot, or the water in the wet well drops to a point below a certain predetermined level.

MIXING CHAMBERS

Eight mixing chambers 19 feet square by 20 feet deep have been provided adjacent the settling basins. The water from the low service pumps discharges into these mixing chambers on one side near the top and leaves the mixing chambers on the opposite side


FIG. 2. OPERATING FLOOR OF THE FILTER ROOM

near the bottom. Mechanical mixers for thoroughly mixing the incoming water with the necessary chemicals are provided in each of these chambers, and consist of three horizontal revolving paddles fastened to pipe crossarms and operated by a motor through a speed reducer. The motors and speed reducers are located on the concrete roof over the mixing chambers, and are housed in with a galvanized wrought iron weatherproof covering. The stirring equipment has been designed to give a velocity of water of approximately 0.6 foot per second. The mixing chambers have a capacity designed for 20 minutes retention period for 32 m.g.d., but at the present time, they

have a capacity of 40 minutes since the plant has but a 16 m.g.d. rate.

## SETTLING BASINS

The settling basins consist of two separate units, each being 180 feet long by 78 feet wide, and 21 feet deep having a combined retention period of 3 hours for 32 m.g.d. or, at present, 6 hours for 16 m.g.d. These basins are located along side the mixing chambers so

FIG. 3. HIGH SERVICE PUMPING STATION

as to prevent the floc from being broken up after it is formed, and to this end conduits for distributing the mixed water to each of the two settling basins have been designed to keep the velocity below one foot per second. Perforated baffles at the inlet permit the water to enter the basin uniformly, and the travel of the water is straight across the basins to the opposite end where the water is collected from the top through perforated baffle walls. There are no intermediate baffles and no changes in direction of travel. Settling basins are drained through hand operated plug valves located in the bottom approximately 44 feet on centers. Settling basins and mixing chambers are covered to prevent ice formation.

## FILTERS

There are eight filter units arranged in two rows separated by a common pipe gallery and operating floor. Each unit has a rated capacity of 2 m.g.d., with the sand area designed for filtration at two gallons per square foot per minute. The operating floor is level with the tops of the filter walls and walks are provided across and around the filters to afford observation during washing. The filter units are provided with a false bottom 20 inches deep serving as a collecting and wash distribution system. The wash water is introduced into this area and is distributed up through the gravel and sand by bronze pipes and umbrella head strainers on 6-inch centers over the entire false bottom. This type of bottom assures equal distribution of the wash water and also permits inspection for loss of sand through the filter units, due to unscrewed or defective strainer heads. The gravel measures 12 inches in depth and is directly over the strainers. It is supported by an 8-inch concrete false bottom floor. The gravel is placed in layers with the coarsest gravel on the bottom and the fine on top, and varies in size from 1 to $\frac{1}{8}$ inch. The gravel is held in place by means of copper screens laid on top of the gravel and held down by means of bronze bolts and washers screwed into the tops of the filter strainers and located on 12 inch centers. On top of the gravel 27 inches of sand had been provided having an effective size of 0.44 millimeters and the uniformity coefficient of 1.48.

The wash water system has been designed to give a maximum rate of wash of 22½ gallons per square foot per minute which is equivalent to a 36-inch rise. The bottoms of the wash troughs which are of steel are placed 14 inches above the top of the sand so as to permit of 50 percent expansion of the sand during washing.

The wash water tank which is a steel structure, having a capacity of 110,000 gallons, is placed in the tower of the coagulant house, and is supplied by a wash water pump located on the main pump room floor.

The filters are controlled from a master controller located on a table in the lobby. This controller automatically regulates the filtration rate of the individual filters. A hydraulic operating table is located on the operating floor in front of each filter, and contains the control mechanism to the hydraulic valves of the filter piping, an indicting loss-of-head gauge, and an indicating rate-of-flow gauge.

The floors and walks around the filter are finished with terrazzo

and the operating tables are of Kasota stone. The walls of the filter room are faced on the inside with an enameled tile.

A clear well in two units has been provided under the entire length of the filters; the units being separated by the pipe gallery. This clear well has but a small capacity since it is only an equalizing basin between the low service and high service pumps. The water from the individual filters in entering this clear well must pass through the flume into which chlorine is introduced. This flume is provided with a mixing chamber so as to thoroughly mix the water with the chlorine. The chlorinated water enters the clear wells at one end and the high service suctions take off from extreme opposite ends of these wells.

### COAGULANT HOUSE

The coagulant house is located over the lobby and is a two story structure. The lower story houses the chemical machinery consisting of dry chemical feed machines for lime and alum, and on the floor above is the chemical storage floor. Chemicals are unloaded on the outside of the building and brought up to the storage floor on a bag elevator, or an electric elevator. A chlorine room, office, laboratory and toilet rooms are located in this building, and the heating system consisting of oil burning steam heating boilers is located in the basement. The wash water tank, as previously mentioned, is located in the tower of this building directly over the chemical storage room and is reached by the circular stairway from the storage room floor.

### HIGH SERVICE PUMP STATION

The high service pump station adjoins the coagulant house. It is designed of sufficient size to house pumps of the capacity of the intake, but, at the present time, it contains one 16 and two 8 m.g.d. motor driven centrifugal units, together with auxiliaries such as vacuum pumps and wash water pump. These pumps take their suction through cast iron headers directly connected to the clear well and discharge into two cast iron lines leading to the distribution system. Both suction and discharge piping are located below the pump room floor in a separate basement, controlling valves being electrically operated from the pump room floor. On the discharge of all pumps there is provided a cone check valve which automatically opens up when the pump starts and shuts down when the pump stops. The high service pumps, as well as the low service pumps in the station on

the shore of the bay, are operated from an operating table located on the balcony above the pump room floor. The floor of the pump station is of quarry tile, and the walls are veneered with the same glazed tile as the filter building.

The total cost of the plant, exclusive of the pipe lines leading from the high service station, was $1,566,000.00 made up of the following contracts:

| | *Dollars* |
|---|---|
| Intake—constructed by Montrose Contracting Company | 537,005 |
| General Contract—constructed by Engstrom and Wynn | 703,600 |
| Filter Equipment—constructed by Norwood Engineering Company | 211,100 |
| Pumps—furnished by Worthington Pump and Machinery Corporation | 31,800 |
| Electrical work—furnished by Robertson Electric and Manufacturing Company | 56,000 |
| Heating and Plumbing—furnished by Scobell and Winston | 26,000 |
| Total | 1,566,000 |

*(Presented before the Central States Section meeting, September 22, 1932.)*

# METER READING

By George H. Fenkell

(*Chief Engineer, Department of Water Supply, Detroit, Mich.*)

The Water Board in Detroit recently made a survey of its meter reading service, and in connection therewith, sent out a questionnaire which covered the ordinary work and problems connected with this branch of operation. The questions were forwarded to 52 cities which are metered fully, or have a substantial number of meters in service. The result was that replies were received from 46 of these cities, and these indicated that with many of them the work of the meter reader has been well considered and that records of the work performed by these employees is available for use. As a result of these inquiries, it appears that in some cities at least the work of the meter reader is given less attention than it deserves and that the importance of his position is under-estimated. In some communities laborers are used to read meters when not otherwise engaged on maintenance or construction work.

## WAGES AND TRAINING

The wages paid meter readers is of interest, for they should receive adequate compensation for work well done. From the information furnished by the questionnaire, it is shown that meter readers receive from $25.00 to $42.00 per week, some of the salaries being paid weekly and some monthly. A Michigan city pays on the basis of quantity production, namely, by piece work, or 2¼ cents for every correct reading. In Detroit the range is from nearly $27.00 to $35.00 per week, depending upon the length of service of the employee, and being further governed by a classification ordinance.

It must here be assumed that the work performed by the meter readers in these different communities is satisfactorily done, that the work these meter readers perform measures up to the standards that usage has established for the class of work. The importance of this work is becoming more apparent to the operators of water works

plants, and efforts are being made to establish rates that are more equitable for both parties concerned. The Indianapolis Water Company has established a method by which meter reading may be measured, has laid down the specific duties of the meter readers, and has provided a point system by which the efficiency and service value of the meter reader may be gauged.

With the majority of consumers, the meter reader is the only contact that the consumer has with the utility. He is the representative of the utility who is intimately familiar with the consumer's water problems. His intercourse at the consumer's premises establishes the friendship between the consumer and the utility.

The meter reader should be trained to know the general policies of the utility and should be thoroughly familiar with the construction operation of a meter. A few weeks spent in the meter shop will give him the requisite knowledge of meters. This fact has been recognized in Detroit to such a degree that, although the Civil Service Commission in that city has a meter reader list, no requisitions have been issued against the list in over five years, for vacancies in the staff are filled by promotion from the meter repair and meter setting staff.

In general utility matters it is difficult to train the reader, and only elementary matters should be presented to him. A wider knowledge of policy can only be acquired through intercourse with the supervising officers, either in conversation, or through frequent staff meetings. Policy training, however, should be such as to impress upon the reader the necessity of not becoming loquacious, for it is better to plead ignorance than to furnish erroneous information.

This only leads to consideration of the main object of meter reading, namely, to put the consumption on the books, so that bills can be rendered for the serivce, and revenue obtained to operate the plant, pay interest on bonded debt, provide sinking funds and produce profits. In order that the above may be accomplished, it is necessary that the meter reader's work be done promptly, accurately and efficiently.

## ACCURACY OF READING

Accuracy of reads is of prime importance, for every effort must be made to insure accuracy in the customer's bill. Nothing so destroys the good-will of a customer as to have mistakes in the billing, whereby it becomes necessary to correct the mistake in subsequent bills.

It appears the general practice among the large cities to permit the

readers to have the previous readings with them while reading, as this tends to greater accuracy, especially when the reader must compute the actual consumption while on the job. It also permits the reader to determine at once whether there is an undue consumption and to serve notice of the same without delay. Much contention may be avoided if the consumer is immediately notified of the large consumption. Such notice should be sent from the utility.

The practice of the reader checking on high or low consumption is not general, as disclosed by the questionnaire, for only about one-half of the cities follow this practice. In the cities where this practice does not prevail, almost the same number of checkers as readers are employed. An example may be found in one frost-belt city, where meters are located in vaults or basements, two meter readers and four checkers are employed to remove meters as well as read them.

### PRODUCTION OF READERS

The number of meters read per day per reader varies from city to city, and these differences may be due to climatic conditions, to locations of meters, or to reader's duties. South of the Ohio River, and on the Pacific coast, most of the meters are placed in curb boxes; a reader can therefore read more meters than he could were he obliged to obtain entrance to buildings.

With the above in mind, it will be seen that no definite quota of readings per day can be fixed. The questionnaire discloses that on the Pacific coast and in the southern states, six cities show an average maximum read of 350 per day. For the same six cities the average minimum production was 200 per day.

With meters placed within buildings, a greater difference in production is noted from the replies, both in the maximum and minimum readings per day. These range from 386 per day in a Michigan city, where readers do not check and are on piece work with no definite hours, down to 50 per day in a Missouri city that is only partially metered. Thirty-one cities reporting had a maximum average of 150 per day and a minimum average of 100 per day.

When the meter is located in a building, the plan has been tried of placing a card on the wall near the meter on which the reader recorded the reading, the date, and the time of day when the reading was taken. This enabled the consumer to check consumption, and gave the department an opportunity to trace the reader in his work. The time required for the reader to make this record has acted as a

deterrent in the adoption of this plan generally. Less water meters can be read in a day than either gas or electric meters, for there is usually only one water meter on the premises, while there may be a number of gas or electric meters. Further, while gas and electric meters are usually man height on the wall and well placed, water meters are generally near the floor, in a furnace room or under a stairway, in fact, in an inconspicuous and somewhat inaccessible position. Naturally, reference is made to meters in buildings, but where meters are in curb boxes, and the ground is free from ice or snow the number of reads of water meters will compare favorably with the reads turned in by gas or electric meter readers.

### FREQUENCY OF READING

This discussion on meter reading will not be complete unless reference is made to the frequency of such reading. Among the questions asked in the questionnaire was one covering this phase of the work, and the replies indicated that 18 cities read water meters monthly; 19, quarterly; 4, every sixty days; 1, twice a quarter; and 4, every six months.

The frequency of reading meters and billing for the consumption depends largely upon local custom and the need of ready funds for the utility. Monthly readings, no doubt, produce cash results of the operation of the utility nearer to the expenditures necessary for producing the services, but such schedule increases the cost to a great extent. The same periodical reading, however, has the advantage that stoppage and errors in reading are more promptly discovered and waste more quickly stopped.

The quarterly period of reading and billing appears to prevail among the cities questioned. This period has advantages, especially in the larger communities, as it lends itself well to cycle billing, by which plan a well ordered flow of revenue may be secured, without the large expenditures for personnel necessary for a similar scheme where meters are read monthly.

Where readings are made at less frequent intervals than monthly, precautions are generally taken to read the larger meters, as those used for industrial and commercial services, more frequently than the domestic meters. Also in some cities, billings are made on the larger consumptions monthly. This has the advantage of levelling the peak loads of revenue and providing some income between the time of expenditures and the due date of general billing.

As stated, the meter reader in most communities is the contact man for the utility. He is thrown more or less on his own resources. He must be more highly disciplined than the members of the office or construction force, which is always under direct supervision. He should be given every legitimate assistance that is within reason to maintain his position through the use of a uniform, badge and other means for identification. A reading book alone is not sufficient.

Questionnaires are usually sent out for the definite purpose of obtaining information for a particular water utility. It is, however, believed that the information received should be made available to all interested and for this reason the questions and answers have been tabulated and are attached hereto.

(*Presented before the Indiana Section meeting, March 29, 1933.*)

*Tabulation of replies received on questionnaire regarding Meter Reading Work, Department of Water Supply, Detroit, September, 1932*

| CITY | POPULATION | NUMBER OF SERVICES | NUMBER OF METERS | LOCATION OF METERS |
|---|---|---|---|---|
| Los Angeles, Calif. | 1,238,048 | 327,452 | 248,217 | Curb box |
| San Francisco, Calif. | 634,394 | 114,400 | 114,400 | Curb box |
| Atlanta, Ga. | 270,366 | 58,000 | 53,000 | Curb box |
| Portland, Ore. | 301,815 | 86,618 | 86,618 | Curb box |
| Louisville, Ky. | 307,745 | 64,313 | 31,824 | Curb box |
| Seattle, Wash. | 365,583 | 82,000 | 82,000 | Curb box |
| San Diego, Calif. | 147,995 | 31,071 | 31,071 | Curb box |
| Tulsa, Okla. | 141,258 | 29,143 | 27,480 | Curb box |
| Dallas, Tex. | 260,475 | 60,700 | 60,700 | Curb box |
| San Antonio, Tex. | 231,542 | 48,000 | 48,000 | Curb box |
| Salt Lake City, Utah | 140,267 | 28,009 | 28,202 | Curb box |
| Jacksonville, Fla. | 129,549 | 25,000 | 25,000 | Curb box |
| *Chattanooga, Tenn. | 119,708 | 26,381 | 26,188 | Curb box |
| Duluth, Minn. | 101,463 | 22,732 | 18,154 | Basement |
| *New Haven, Conn. | 162,655 | 40,867 | 20,000 | Basement |
| Grand Rapids, Mich | 168,592 | 38,480 | 38,480 | Basement |
| Kansas City, Mo. | 399,746 | 91,248 | 80,349 | Basement |
| Minneapolis, Minn. | 464,356 | 90,000 | 90,000 | Basement |
| Portland, Maine | 70,810 | 21,205 | 11,095 | Basement |
| Akron, Ohio | 255,040 | 53,350 | 54,700 | Basement |
| Omaha, Nebr. | 214,006 | 51,670 | 50,950 | Basement |
| Hartford, Conn. | 164,072 | 27,249 | 26,204 | Basement |
| Rochester, N. Y. | 328,132 | 60,200 | 60,000 | Basement |
| Fort Wayne, Ind. | 114,946 | 28,500 | 28,500 | Basement |
| Springfield, Mass. | 149,900 | 23,000 | 23,000 | Basement |

| CITY | POPULATION | NUMBER OF SERVICES | NUMBER OF METERS | LOCATION OF METERS |
|---|---|---|---|---|
| Toledo, Ohio | 290,718 | 68,000 | 68,000 | Basement |
| Manchester, N. H. | 76,834 | 10,639 | 10,763 | Basement |
| Cincinnati, Ohio | 451,160 | 95,000 | 92,000 | Basement |
| Buffalo, N. Y. | 573,076 | 99,066 | 16,696 | Basement |
| *St. Louis, Mo. County | | 35,346 | 34,628 | Basement |
| Flint, Mich. | 156,492 | 30,357 | 30,357 | Basement |
| Des Moines, Iowa | 142,559 | 31,529 | 31,360 | Basement |
| Philadelphia, Pa. | 1,950,961 | 455,000 | 194,000 | Basement |
| *Indianapolis, Ind. | 364,161 | 70,997 | 70,389 | Basement |
| *Paterson, N. J. | 138,512 | 22,625 | 22,625 | Basement |
| Washington, D. C. | 486,869 | 99,563 | 87,033 | Basement |
| Chicago, Ill. | 3,376,438 | 420,000 | 110,000 | Basement |
| St. Louis, Mo. | 821,960 | 133,495 | 14,345 | Basement |
| Wilmington, Del. | 106,597 | 25,150 | 25,589 | Basement |
| Cleveland, Ohio | 900,429 | 165,000 | 161,700 | Basement |
| Kansas City, Kan. | 121,857 | 26,280 | 26,280 | Basement |
| Hackensack, N. J. (Dist.) | 24,568 | 72,243 | 72,243 | Basement |
| Columbus, Ohio | 290,564 | 61,000 | 60,500 | Basement |
| St. Paul, Minn. | 271,606 | 56,329 | 56,179 | Basement |
| Providence, R. I. | 252,981 | 46,000 | 45,000 | Basement |
| New York City, N. Y. | 6,930,446 | 615,727 | 154,478 | Basement |
| Detroit, Mich. | 1,568,662 | 272,035 | 271,335 | Basement |

* Privately owned water companies.

| CITY | HOW OFTEN READ | NUMBER OF METER READERS | NUMBER INVESTIGATING AND CHECKING READINGS | MAXIMUM PER MAN PER DAY |
|---|---|---|---|---|
| Los Angeles, Calif. | Monthly | 32 | Regular readers | 627 |
| San Francisco, Calif. | Monthly | 16 | Regular readers | 350 |
| Atlanta, Ga. | Monthly | 8 | Regular readers | 300 |
| Portland, Ore. | Monthly | 8 | Regular readers | 300 |
| Louisville, Ky. | Monthly | 5 | 1 | 280 |
| Seattle, Wash. | Monthly | 12 | 2 | 400 |
| San Diego, Calif. | Monthly | 4 | Regular readers | 375 |
| Tulsa, Okla. | Monthly | 7 | 5 | 400 |
| Dallas, Tex. | Monthly | 6 | 6 | 325 |
| San Antonio, Tex. | Monthly | 10 | Regular readers | 400 |
| Salt Lake City, Utah | Monthly | 2 | 1 | 200 |
| Jacksonville, Fla. | Monthly | 4 | 5 | 300 |
| Chattanooga, Tenn. | Monthly | 5 | Regular readers | 350 |
| Duluth, Minn. | Monthly | 14 | Regular readers | 285 |
| New Haven, Conn. | Quarterly | 6 | 1 | 125 |

| CITY | HOW OFTEN READ | NUMBER OF METER READERS | NUMBER INVESTIGATING AND CHECKING READINGS | MAXIMUM PER MAN PER DAY |
|---|---|---|---|---|
| Grand Rapids, Mich | Quarterly | 5 | 1 | 140 |
| Kansas City, Mo | Monthly | 23 | Regular readers | 135 |
| Minneapolis, Minn | Quarterly | 25 | 4 | 120 |
| Portland, Maine | Quarterly | 6 | 1 | 100 |
| Akron, Ohio | Quarterly | 12 | 3 | 175 |
| Omaha, Nebr | Quarterly | 6 | 2 | 200 |
| Hartford, Conn | Bi-monthly | 6 | 1 | 110 |
| Rochester, N. Y | Quarterly | 12 | 1 | 95 |
| Fort Wayne, Ind | Monthly | 8 | 4 | 150 |
| Springfield, Mass | Twice quarterly | 6 | 1 | 175 |
| Toledo, Ohio | Read quarterly—bill semi-annually | 13 | 4 | 160 |
| Manchester, N. H | Quarterly | 4 | 2 | 125 |
| Cincinnati, Ohio | Quarterly | 16 | Regular readers | 150 |
| Buffalo, N. Y | Quarterly | 6 | Done by meter shop | 100 |
| St. Louis, Mo. County | Quarterly | 4 | 7 | 260 |
| Flint, Mich | Quarterly | 2 | 1 | 386 |
| Des Moines, Ia | Quarterly | 5 | Regular readers | 300 |
| Philadelphia, Pa | Semi-annually | 40 | 6 | 85 |
| Indianapolis, Ind | Monthly | 19 | Regular readers | 180 |
| Paterson, N. J | Quarterly | 12 | Regular readers | 125 |
| Washington, D. C | Semi-annually | 7 | 3 | 200 |
| Chicago, Ill | Bi-monthly | 57 | Regular readers | 60 |
| St. Louis, Mo | Every 60 days | 8 | 1 | 50 |
| Wilmington, Del | Monthly | 8 | Regular readers | 225 |
| Cleveland, Ohio | Semi-annually | 14 | 8 | 150 |
| Kansas City, Kans | Monthly | 16 | Regular readers; also read electrical meters | 354 |
| Hackensack, N. J. (Dist.) | Quarterly | 9 | 1 | 200 |
| Columbus, Ohio | Monthly | 8 | 2 | 200 |
| St. Paul, Minn | Quarterly | 13 | 2 | 70 |
| Providence, R. I | Quarterly | 9 | Regular readers | 100 |
| New York City, N. Y | Semi-annually | 57 | 35 | 58 |
| Detroit, Mich | Quarterly | 47 | 13 (34 on regular reading) | 203 |

| CITY | MINIMUM PER MAN PER DAY | NUMBER OF WORKING HOURS PER DAY | ARE METERS READ ON RAINY DAYS? | IF NONE READ, HOW EMPLOYED? |
|---|---|---|---|---|
| Los Angeles, Calif. | 450 | 8 | Yes | Regular quota |
| San Francisco, Calif. | 150 | 8 | Yes | |
| Atlanta, Ga. | 150 | 8 | Yes | |
| Portland, Ore. | 200 | 8 | Yes | |
| Louisville, Ky. | 215 | 8 | Yes, except downpour | Odd jobs |
| Seattle, Wash. | 150 | 8 | Yes | |
| San Diego, Calif. | 325 | 8 | No | Not much time lost |
| Tulsa, Okla. | | 8 | No | Work inside |
| Dallas, Tex. | 325 | 8 | No | Seldom occurs |
| San Antonio, Tex. | 290 | 8 | Yes | |
| Salt Lake City, Utah | 200 | 8 | Yes | |
| Jacksonville, Fla. | 200 | 8 | Yes | |
| Chattanooga, Tenn. | 250 | 10 | Yes | |
| Duluth, Minn. | 225 | 8 | Yes | |
| New Haven, Conn. | 100 | 8 | Yes | |
| Grand Rapids, Mich. | 115 | 8½ | Yes | |
| Kansas City, Mo. | 75 | 8 | Yes | |
| Minneapolis, Minn. | 80 | 8 | Yes | |
| Portland, Maine | 50 | 8 | No | Repairing and testing meters |
| Akron, Ohio | 150 | 8 | Yes | |
| Omaha, Nebr. | 135 | 8 | Yes | |
| Hartford, Conn. | 100 | 8 | Yes | |
| Rochester, N. Y. | 95 | 7 | Yes | |
| Fort Wayne, Ind. | 125 | 8 | Yes | |
| Springfield, Mass. | 125 | 7½ | No | Office work |
| Toledo, Ohio | 100 | 8 | Yes | |
| Manchester, N. H. | 80 | 8–9 | Yes | |
| Cincinnati, Ohio | 150 | 8 | Yes | |
| Buffalo, N. Y. | 30 | 8 | Yes | |
| St. Louis, Mo. County | 130 | 9 | Yes | |
| Flint, Mich. | 191 | 8 | Yes | |
| Des Moines, Ia. | 100 | 8 | Yes | |
| Philadelphia, Pa. | 60 | 8 | Yes | |
| Indianapolis, Ind. | 180 | 8 | Yes | |
| Paterson, N. J. | 60 | 7 | Yes | |
| Washington, D. C. | 75 | 8 | Yes | |
| Chicago, Ill. | 40 | 7 | Yes | |
| St. Louis, Mo. | 40 | 8 | Yes | |

| CITY | MINIMUM PER MAN PER DAY | NUMBER OF WORKING HOURS PER DAY | ARE METERS READ ON RAINY DAYS? | IF NONE READ, HOW EMPLOYED? |
|---|---|---|---|---|
| Wilmington, Del. | 150 | $8\frac{3}{4}$ | No | Excused |
| Cleveland, Ohio | 100 | 8 | Yes | |
| Kansas City, Kan. | 178 | 8 | Yes | |
| Hackensack, N. J. (Dist.) | 120 | 8 | No | Miscellaneous office work |
| Columbus, Ohio | | 8 | Yes | |
| St. Paul, Minn. | 70 | 8 | Yes | |
| Providence, R. I. | 90 | 8 | Yes | |
| New York City, N. Y. | 25 | 8 | Yes | |
| Detroit, Mich. | 135 | 8 | Yes, if not too stormy | In office |

| CITY | NUMBER READ ON RAINY DAYS | DO READERS CARRY PREVIOUS READINGS? | DO READERS COMPUTE CONSUMPTION ON PREMISES? | DO READERS CHECK HIGH OR LOW CONSUMPTION? |
|---|---|---|---|---|
| Los Angeles, Calif. | Regular quota | Yes | Yes | Yes |
| San Francisco, Calif. | Regular quota | Yes | Yes | Yes |
| Atlanta, Ga. | 100 | Yes | Yes | Yes |
| Portland, Ore. | Regular quota | Yes | No | Yes |
| Louisville, Ky. | 215 | Yes | Yes | Yes |
| Seattle, Wash. | Regular quota | Yes | No | No |
| San Diego, Calif. | 45 per hour | Yes | Yes | Yes |
| Tulsa, Okla. | | Yes | No | No |
| Dallas, Tex. | | Yes | No | No |
| San Antonio, Tex. | Regular quota | Yes | Superficially | Superficially |
| Salt Lake City, Utah | 200 | Yes | No | Yes |
| Jacksonville, Fla. | | Yes | No | No |
| Chattanooga, Tenn. | 100–200 | Yes | Yes | No |
| Duluth, Minn. | 230 | Yes | Yes | Yes |
| New Haven, Conn. | 100 | Yes | Yes | No |
| Grand Rapids, Mich. | 115–125 | Yes | No | No |
| Kansas City, Mo. | 110 | Yes | No | No |
| Minneapolis, Minn. | 80–120 | Yes | Yes | Yes |
| Portland, Maine | | Yes | Yes | No |
| Akron, Ohio | | Yes | Roughly | Yes |
| Omaha, Nebr. | Regular quota | Yes | No | Yes |
| Hartford, Conn. | 100 | Yes | Yes | Yes |
| Rochester, N. Y. | 95 | Yes | Yes | Yes |
| Fort Wayne, Ind. | | Yes | No | No |

| CITY | NUMBER READ ON RAINY DAYS | DO READERS CARRY PREVIOUS READINGS? | DO READERS COMPUTE CONSUMPTION ON PREMISES? | DO READERS CHECK HIGH OR LOW CONSUMPTION? |
|---|---|---|---|---|
| Springfield, Mass. | | Yes | Yes | Yes |
| Toledo, Ohio | Regular quota | Yes | No | No |
| Manchester, N. H. | | Yes | Yes | No |
| Cincinnati, Ohio | 150 | Yes | Roughly | Yes |
| Buffalo, N. Y. | Regular quota | Yes | Yes | No |
| St. Louis, Mo. County | | Yes | No | No |
| Flint, Mich. | Regular quota | No | | No |
| Des Moines, Ia. | 140 | Yes | No | No |
| Philadelphia, Pa. | Governed by weather | Yes | No | No |
| Indianapolis, Ind. | Regular quota | Yes | Yes | Yes |
| Paterson, N. J. | Regular quota | Yes | No | Yes |
| Washington, D. C. | 60 | Yes | No | No |
| Chicago, Ill. | | Yes | No | Superficially |
| St. Louis, Mo. | 40 | Yes | No | Yes |
| Wilmington, Del. | | Yes | Yes | No |
| Cleveland, Ohio | 135 | Yes | Yes | Yes |
| Kansas City, Kan. | 150 | Yes | No | Extreme cases |
| Hackensack, N. J. (Distr.) | | Yes | Yes | Yes |
| Columbus, Ohio | | Yes | No | Limited |
| St. Paul, Minn. | Regular quota | Yes | Yes | Yes |
| Providence, R. I. | 60 | Yes | Yes | Yes |
| New York City, N. Y. | Regular quota | Yes | No | Yes |
| Detroit, Mich. | Governed by weather | Yes | Yes | Limited |

| CITY | QUALIFICATIONS FOR READERS | HOW PAID | IS BONUS GIVEN | VACATION WITH PAY? |
|---|---|---|---|---|
| Los Angeles, Calif. | Special requirements | Monthly | No | Yes |
| San Francisco, Calif. | Civil Service Examination | Monthly | No | Yes |
| Atlanta, Ga. | Special training | Monthly | No | Discontinued |
| Portland, Ore. | Civil Service Examination | Monthly | No | Yes |
| Louisville, Ky. | (21 to 30) Good physical condition. Common school education | By hour | No | No |
| Seattle, Wash. | (21 to 35) Civil Service | Monthly | No | Yes |

| CITY | QUALIFICATIONS FOR READERS | HOW PAID | IS BONUS GIVEN | VACATION WITH PAY? |
|---|---|---|---|---|
| San Diego, Calif. | Special requirements | Yearly | No | Yes |
| Tulsa, Okla. | No special requirements | Monthly | No | Yes |
| Dallas, Tex. | Good physical condition | Monthly | No | Yes |
| San Antonio, Tex. | No definite specifications | Monthly | No | Yes |
| Salt Lake City, Utah. | No special requirements | Monthly | No | Yes |
| Jacksonville, Fla. | (21 to 55) General ability | Semi-monthly | No | Yes |
| Chattanooga, Tenn. | Young men. Good physical condition. Fair education | By day | No | No |
| Duluth, Minn. | (20 to 46) Good physical condition. High school education | Monthly | No | Yes |
| New Haven, Conn. | Fitness for job and good references | Weekly | No | Yes |
| Grand Rapids, Mich. | (25 to 40) Good physical condition. High school education | By month and hour | No | Yes |
| Minneapolis, Minn. | Civil Service Examination. Legal age and required education | Monthly | No | Yes |
| Kansas City, Mo. | Special examination | Annual salary | No | Yes |
| Portland, Maine | Active men. High school education | Weekly | No | Yes |
| Akron, Ohio | (21 to 50) Good physical condition. High school education | Salary and hourly rate | No | Salaried men only |
| Omaha, Nebr. | Young men. Good physical condition | Monthly | No | Yes |
| Hartford, Conn. | Selected from factory force. Not over 35 years of age | Yearly | No | Yes |
| Rochester, N. Y. | (18 to 45) Physical examination | Yearly | No | Yes |
| Fort Wayne, Ind. | No special requirements | Monthly | No | Yes |
| Springfield, Mass. | Civil Service list | Weekly | No | Yes |
| Toledo, Ohio | Civil Service Examination | Monthly | No | Yes |
| Manchester, N. H. | Young men. High school education | By day | No | 1 week |

| CITY | QUALIFICATIONS FOR READERS | HOW PAID | IS BONUS GIVEN | VACATION WITH PAY? |
|---|---|---|---|---|
| Cincinnati, Ohio | (21 to 45) High school education. Good physical condition. Tact | Annually | No | Yes |
| Buffalo, N. Y. | Civil Service list | Annual salary | No | Yes |
| St. Louis, Mo. County | Special requirements | Hourly rate | No | No |
| Flint, Mich. | | Per read | No | No |
| Des Moines, Ia. | Over 18 years of age | Per day | No | No |
| Philadelphia, Pa. | Over 21. Good physical condition | Annual salary | No | Yes |
| Indianapolis, Ind. | (21 to 25) Good physical condition. High school education | Monthly | No | Yes |
| Paterson, N. J. | | Weekly | No | Yes |
| Washington, D. C. | Under 40 years—trial. No physical disability | Per day | No | Yes |
| Chicago, Ill. | No special requirements | Annual salary | No | Yes |
| St. Louis, Mo. | (25 to 60) Good physical condition. Fair education | Monthly | No | Yes |
| Wilmington, Del. | No special requirements | Weekly | No | 8 days |
| Cleveland, Ohio | Common school education. No age limit | Hourly rate | No | No |
| Kansas City, Kan. | Common school education. Good physical condition | Monthly | No | Yes |
| Hackensack, N. J. | (22 to 35) Good physical condition. High school education | Annual salary | No | Yes |
| Columbus, Ohio | Civil Service Examination | Monthly | No | Yes |
| St. Paul, Minn. | (21 to 50) Good vision and physical condition | Annual salary | No | Yes |
| Providence, R. I. | Active and intelligent | Salary | No | Yes |
| New York City, N. Y. | Civil Service Examination | Annual salary | No | Yes |
| Detroit, Mich. | Civil Service Examination | Annual salary | No | Yes |

| CITY | SICK LEAVE ALLOWANCE WITH PAY? | ARE READERS UNIFORMED? | IF NOT, HOW IDENTIFIED? | NUMBER OF UNMETERED SERVICES |
|---|---|---|---|---|
| Los Angeles, Calif. | Yes | No | Badge | None |
| San Francisco, Calif. | Yes | No | | None |
| Atlanta, Ga. | No | No | Badge | None |
| Portland, Ore. | No | No | Badge | None |
| Louisville, Ky. | No | No | Badge | 33,390 |
| Seattle, Wash. | No | No | | None |
| San Diego, Calif. | 15 days | No | | None |
| Tulsa, Okla. | Yes | No | Badge | 1,663 |
| Dallas, Tex. | Yes | No | Badge | None |
| San Antonio, Tex. | Yes | No | | Only fire lines |
| Salt Lake City, Utah. | Yes | No | Badge | None |
| Jacksonville, Fla. | Limited | No | Badge | None |
| Chattanooga, Tenn. | Group Insurance and Workmen's Compensation | No | | 193 fire lines |
| Duluth, Minn. | Yes | No | Route book | None |
| New Haven, Conn. | Yes | No | Badge and card | 21,000 |
| Grand Rapids, Mich. | Monthly men only | No | Cap and badge | None |
| Minneapolis, Minn. | Yes—Physician's Certificate | No | Credentials | None |
| Portland, Maine | Yes | No | Badge and card | 10,000 |
| Akron, Ohio | Salaried men | No | Badge | Only fire lines |
| Omaha, Nebr. | Part of salary not to exceed 26 weeks | No | Cap, badge and card | 115 |
| Hartford, Conn. | Yes | No | Card | 1,045 |
| Rochester, N. Y. | Yes | No | Badge | 162 fire lines |
| Fort Wayne, Ind. | Yes | No | Badge | Only sprinkler line systems |
| Springfield, Mass. | Yes | Yes | Uniform | None |
| Toledo, Ohio | For short time | No | Badge | None |
| Manchester, N. H. | Yes | No | Card and photo | None |

| CITY | SICK LEAVE ALLOWANCE WITH PAY? | ARE READERS UNIFORMED? | IF NOT, HOW IDENTIFIED? | NUMBER OF UNMETERED SERVICES |
|---|---|---|---|---|
| Cincinnati, Ohio | 12 days | No | Badge | None |
| Buffalo, N. Y. | 30 days | No | Badge | 82,370 |
| St. Louis, Mo. County | Paid to following Thursday evening | No | Cap and badge | 718 |
| Flint, Mich. | No | No | Badge | |
| Des Moines, Ia. | No | No | Badge | 169 |
| Philadelphia, Pa. | Yes | Yes | Badge and card | 261,000 |
| Indianapolis, Ind. | Yes | Yes | | Few fire lines and city accounts |
| Paterson, N. J. | Discretionary | No | Card and photo | None |
| Washington, D. C. | No | No | Badge | 12,530 |
| Chicago, Ill. | Yes | No | Badge, card, photo | 310,000 |
| St. Louis, Mo. | 2 weeks full pay, 4 weeks ½ pay | No | Badge | 119,150 |
| Wilmington, Del. | Discretionary | Yes | Badge | None |
| Cleveland, Ohio | No | No | Badge and card | 3,300 |
| Kansas City, Kan. | Discretionary | No | Badge | None |
| Hackensack, N. J. | Yes | Yes | | None |
| Columbus, Ohio | Limited | No | Badge | 500 |
| St. Paul, Minn. | Two weeks | No | Badge and card photo | 150 |
| Providence, R. I. | Yes | No | Badge | 600 flat rates, 500 fire lines |
| New York City, N. Y. | Deducted from vacation | No | Badge and papers | 462,961 |
| Detroit, Mich. | 15 days | Uniform cap | | 700 |

# REGULATION OF THE COLORADO RIVER

By C. C. Elder

*(Hydrographic Engineer, Metropolitan Water District of Southern California, Los Angeles, Calif.)*

The Colorado is the champion "bad actor" of all the large rivers of the United States, and probably of the world, in its present unregulated and but slightly utilized condition. Its potential destructiveness is limited only by reason of the relatively scanty population and resources of its lower valleys, which in turn have been retarded in development by the ever-present threat of an overwhelming flood. The run-off is extremely flashy and undependable, varying from absolutely dry at the Mexican boundary line on numerous occasions during 7 of the last 30 years to maximum peak flows of over 200,000 second feet, or 10 times the mean. Annual discharges in percent of the mean have ranged from 35 for 1931 to 163 percent in 1909. Rainfall averages less than 3 inches over much of the basin, and for the entire watershed of 244,000 square miles, is only 10.7 inches as an annual mean. The total discharge plus consumptive use amounts to 12.5 percent of the precipitation, or about $1\frac{1}{3}$ inches of run-off from the drainage basin. The immense silt load adds greatly to the difficulty of controlling the stream, and is in fact chiefly responsible for the flood problem, having been the means by which the river has elevated itself along the crest of its delta ridge, high above the basin's most fertile irrigated areas and prosperous towns.

After long years of detailed, thorough engineering investigations (and nearly as long a period of negotiations and bitter political controversies), the United States is finally making the regulation of the Colorado River a reality by the construction of the Boulder Canyon reservoir. The project proved to be far beyond the powers of any lesser agency because of the international as well as interstate complications which are involved. With seven more or less sovereign American states vitally concerned, besides two in Mexico, and a jealous guard maintained over the real or fancied interests of countless individuals, corporations, municipalities, and organizations or asso-

ciations of every description, no progress was possible until the Boulder Canyon Project Act was passed by Congress, and this was then further reinforced by the recent far-reaching decision of the United States Supreme Court.

## OBJECTIVES OF REGULATION

The great reservoir, with a storage capacity of 30,500,000 acre feet (ten trillion gallons, astronomically speaking) is planned and will be operated to accomplish the following purposes listed in the order of their relative importance, according to the terms of the Boulder Canyon Project Act and the Colorado River Compact:

1. Flood control and the improvement of navigation (the upper 9,500,000 acre feet of storage capacity being reserved solely for this use).
2. Run-off regulation to make feasible the diversion of water for domestic use (the aqueduct of the Metropolitan Water District of Southern California being the chief example, with a contract signed 1½ years ago for stored water).
3. Storage for irrigation (the All-American Canal to Imperial and Coachella Valleys being already authorized with other projects under investigation).
4. Hydro-electric power generation (power contracts being depended on to repay the cost of the reservoir with interest, within 50 years).
5. Silt removal (by deposit in and above the reservoir basin).
6. Decrease of dissolved solids (by conservation of the very fresh, pure water of the spring floods, now largely wasted into the ocean).

## DISCHARGE RECORDS

The Colorado River has been measured continuously and accurately during the last 30 years at Yuma, just below the mouth of the Gila River. The recorded mean flow is 16,000,000 acre feet annually (22,000 second feet), but allowing for increased upstream depletion during this period, the present average flow at Yuma is approximately 21,000 c.f.s. Boulder Canyon dam site is the point of maximum discharge on the river. The reconstructed mean run-off there (present run-off plus upstream consumption) is 17,350,000 acre feet (24,000 c.f.s.) as a mean for the last 80 years, estimated from the available measurements, supplemented by fragmentary upstream records and by comparison with gage heights and inflow of Great Salt Lake. Upon the completion of the Boulder Canyon reservoir, about 1938, the reservoir inflow will probably average 20,800 c.f.s., as computed by the United States Bureau of Reclamation. Fifty years later, according to the same authority, the inflow may be reduced to 16,500 c.f.s., if the development of the Upper Basin proceeds as permitted by

the Colorado River Compact (though many of the proposed projects now appear relatively infeasible).

The necessity for discharge regulation on the Colorado River and the results that will be accomplished by it are best shown graphically

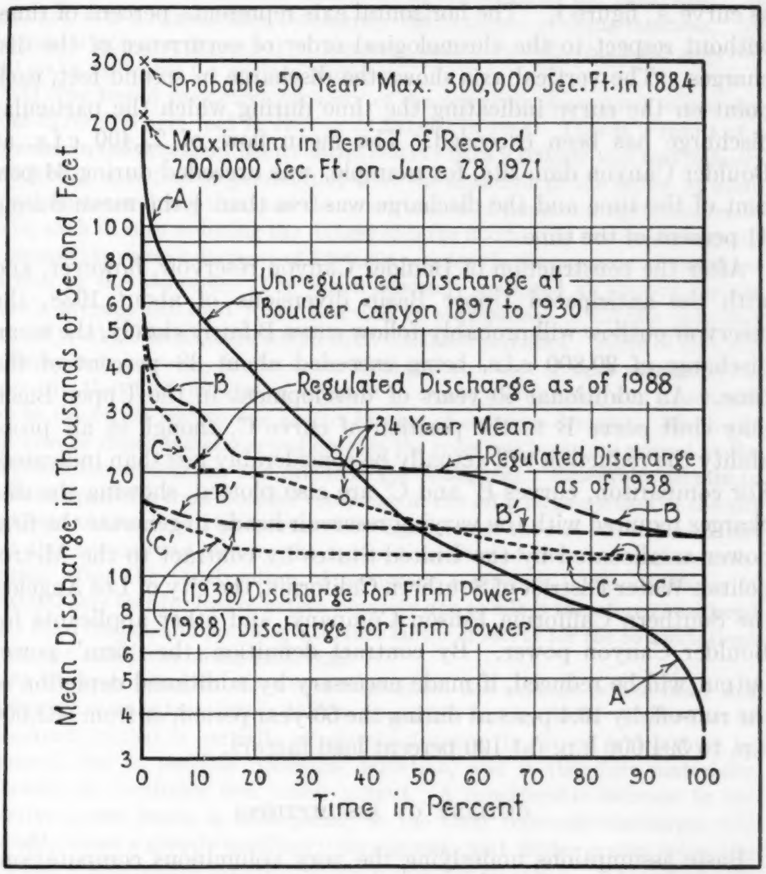


FIG. 1. COLORADO RIVER AT BOULDER CANYON. PRESENT UNREGULATED DISCHARGE AND FUTURE DISCHARGE AS REGULATED BY BOULDER CANYON RESERVOIR. BASED ON 34-YEAR PERIOD OF RECORD 1897 TO 1930

in the form of duration curves. These indicate conditions "before and after taking," to quote from the patter of the patent medicine man. Fortunately, the professional comparison ends as quickly as begun, because engineering remedies as prescribed for curing Nature's

ailments and defects have the unique habit of behaving in general just as predicted, in spite of that "innate cussedness of inanimate matter," of which the Colorado River often displays such an unpleasant surplus.

Present natural conditions, during the period of record, are plotted as curve A, figure 1. The horizontal axis represents percent of time, without respect to the chronological order of occurrence of the discharges. The vertical axis shows the discharge in second feet, each point on the curve indicating the time during which the particular discharge has been exceeded. The mean flow of 22,400 c.f.s. at Boulder Canyon dam site, for example, was exceeded during 34 percent of the time and the discharge was less than ½ the mean during 41 percent of the time.

After the construction of Boulder Canyon reservoir, however, and with the anticipated Upper Basin diversions of about 1938, the reservoir outflow will probably follow curve B fairly closely, the mean discharge of 20,800 c.f.s. being exceeded about 38 percent of the time. An additional 50 years of development in the Upper Basin may shift curve B to the position of curve C, though in all probability the reduction will actually be considerably less than indicated. For comparison, curves B′ and C′ are also plotted, showing the discharges required with the varying reservoir heads to generate the firm power as allocated by the United States by contract to the Metropolitan Water District of Southern California, the city of Los Angeles, the Southern California Edison Company, and other applicants for Boulder Canyon power. By contract definition, the "firm" power output will be reduced, if made necessary by additional depletion of the run-off, by 10.4 percent during the 50-year period, or from 663,000 h.p. to 594,000 h.p. (at 100 percent load factor).

## OUTLINE OF ASSUMPTIONS

Basic assumptions underlying the very voluminous computations from which the curves of figure 1 are derived include the following:

(1) Power plant efficiency of 83 percent, with the large, modernly designed units, as planned for installation.

(2) Upstream depletion, as of 1928, totaling 2,760,000 acre feet annually, increasing at a uniform rate of development to 3,480,000 acre feet annually by 1938 and to 6,600,000 acre feet annually by 1988. The Colorado River Compact permits a maximum of 7,500,000 acre feet consumption in the Upper Basin so that a slight additional depletion may occur, if projects physically and economically feasible can be found. But even in case this full depletion

occurs, the margin of run-off over and above that required for firm power generation will still be more than 20 percent.

(3) Reservoir evaporation at the rate of 5.0 feet depth per year, or an average of nearly 600,000 acre feet. This apparently large amount is but 4 to 5 percent of the present and ultimate run-offs, respectively, and the reservoir is therefore far more efficient than most in operation in the Southwest. In any case, it is not a net loss, but merely the "expense of doing business," for the loss is not over 6 percent of the now wasted run-off which the reservoir will make utilizable for various purposes.

(4) The top of the active capacity of the reservoir is assumed to increase from 21,000,000 acre feet in 1938 to 23,500,000 in 1988. This is a result of a decrease in the necessary flood control reserve from 9,500,000 acre feet initially to 4,000,000 acre feet 50 years later, after the depletion of the inflow by additional upstream irrigation, and the construction of numerous upstream reservoirs, each in turn reducing the danger of large floods. In the meantime, silt is assumed to cause a decrease of 3,000,000 acre feet in the capacity of the upper portion of the reservoir. The figure generally accepted at present for the river's average silt load (both bed and in suspension) is 137,000 acre feet annually, which in 50 years would total 6,850,000 acre feet. Some of this will be deposited, however, in the lower 5,000,000 acre feet of dead storage of the reservoir, the chief function of which is to create power head, and which will not be drawn on for storage except in case of extreme drought. Much silt will also be deposited above and outside the reservoir basin, as proved at the Elephant Butte reservoir and others in the Southwest. Reservoirs certain to be built upstream from Boulder Canyon will cut off a large portion of the silt load, and the total will be decreased by depletion of the run-off, to the extent that this occurs, and also by the reduced velocity of the river and its tributaries, after the construction of numerous reservoirs. The allowance of 3,000,000 acre feet for loss of active capacity due to silt is therefore considered more than liberal, and provides a further factor of safety for the computations of the net safe yield of the reservoir.

(5) Corresponding to the above capacities, the average power head will gradually increase from 520 in 1938 to about 540 feet by 1988. This effect is important, in that it partially offsets the decrease in run-off which must be assumed, due to possible upstream depletion, and it therefore materially increases the available firm power output. A considerable increase in the effective power heads is anticipated, as the clear reservoir discharges will probably cause a greatly modified river regimen, with flatter grades below the dam and a progressive lowering of the tail water elevation. This effect will of course be much less if the regulated river is permitted to meander freely through the Mojave and other valleys below the dam site, but irrigation developments in these valleys will doubtless include river control and channel straightening projects. An increase of 5 percent or more in the power head at the dam in this manner is not impossible. In combination with the factors previously mentioned, of decreasing flood control reserve, liberal estimate of loss of capacity by silt, and very conservative allowance for upstream depletion, the effect of the actual reduction in inflow may be fully offset by these favorable changes in assumptions, and it may therefore never be found necessary to reduce the allocated firm power output, as provided by contract.

## COLORADO RIVER SILT

The generally accepted estimate of the average annual silt load in the lower Colorado River below the canyon section is 137,000 acre feet, equivalent to a mean of 0.85 percent by volume or (at 85 pounds per cubic foot) 1.16 percent by weight. Bed load is roughly estimated at 20 percent of the total. Monthly means by weight (of the suspended load only) ranged during the period of record from a minimum of 0.13 in December, 1917 to a maximum of 2.81 percent in September, 1925. An analysis of some 4,000 silt measurements at Yuma, with no flow in the Gila River, showed the maximum silt percentage to be present with an average discharge of 26,000 c.f.s.

TABLE 1

*Rate of settling of silt*

| PARKER DAM SITE | SUSPENDED MATTER (DRIED AT 105°C.) | PERCENT |
|---|---|---|
| | *p.p.m.* | |
| Raw Colorado River | 26,770 | 100.00 |
| After settling for 5 minutes | 15,620 | 58.30 |
| After settling for 10 minutes | 8,480 | 31.70 |
| After settling for 15 minutes | 830 | 3.10 |
| After settling for 20 minutes | 210 | 0.80 |
| After settling for 30 minutes | 170 | 0.60 |
| After settling for 45 minutes | 60 | 0.22 |
| After settling for 1 hour | 50 | 0.19 |
| After settling for 1½ hours | 45 | 0.17 |
| After settling for 2 hours | 40 | 0.15 |
| After settling for 12 hours | 0 | 0.00 |

This is also the minimum discharge at which the mean velocity of the stream reaches 6.0 feet per second, which is exceeded but little with higher discharges.

If 137,000 acre feet of silt should be deposited annually in the Boulder Canyon reservoir, it would have a useful life of 223 years, which is a much longer period than most engineering structures are designed for. Actually, however, due to the various reasons previously mentioned, the average annual deposit of silt will be far less, and will probably not exceed 3,000,000 acre feet in 50 years. At this rate, the reservoir would continue to function for storage as well as power purposes, for more than five centuries.

The silt is of such a nature as to settle easily, quickly, and com-

pletely. Recent tests (August 16, 1931) with a discharge of about 5,000 c.f.s. at the Parker dam site, 150 miles below the Boulder Canyon dam, and with several Arizona tributaries in flood (silt from the latter generally being slower to settle as well as greater in percent), showed the data in table 1.

### COLORADO RIVER DISSOLVED SOLIDS

The importance of the Boulder Canyon reservoir in regulating the river's salt content is not as generally recognized as the effect on the discharge itself. Without the reservoir, a uniform diversion would have an average annual salt content of 770 p.p.m. (3 year mean of 10 day composite samples for 1925 to 1928). This is 46 percent more than the similar average of 528 p.p.m. as weighted in proportion to the discharge, which will be approximately the effect of the reservoir regulation.

Detailed analyses of weekly or 10-day composite samples have been made at the Grand Canyon station since 1925, and are now published for the first three years of this period. During a portion of this time, analyses are also available at Lees Ferry, Topock, and Yuma. Total dissolved solids average 5 percent less at Lees Ferry, as compared with the water at Grand Canyon, and about as much more at Topock. The differences being small and very uniform, analyses are now made only of samples taken at Grand Canyon and Yuma.

Salt contents at Grand Canyon vary from about 200 during spring floods to nearly 1500 p.p.m. at extreme low water stages. Little regularity is evident when the individual analyses are plotted but by grouping the 125 available analyses of composite samples and plotting the averages (points 1 to 9, figure 2) a smooth mathematical curve (A) results. Samples during the late summer range as high as curve (B), however, due to the greater salt contents of flashy floods from Arizona tributaries.

Curve A has the equation:

$$QS = 11{,}500 + (Q - 21.7)\,\Delta S$$

where $(Q)$ is the mean discharge in 1,000 c.f.s. $(S)$ is the dissolved solids in parts per million, and $\Delta S$ is the dissolved solids of the increment of discharge, $\Delta Q$, above or below the mean discharge. $\Delta S$ is practically constant for discharges above the mean. The equation of curve A therefore reduces to $S = \dfrac{8100}{Q} + 155$ for values of $Q$ greater than 22,000 c.f.s.

A practical application of this curve was made by computing the average dissolved solids for the seasons 1928–29 and 1929–30 from the mean monthly discharges, using curve B for the months of August and September of each season to allow for the heavy Arizona rains and floods which occurred. The estimated mean weighted salt con-

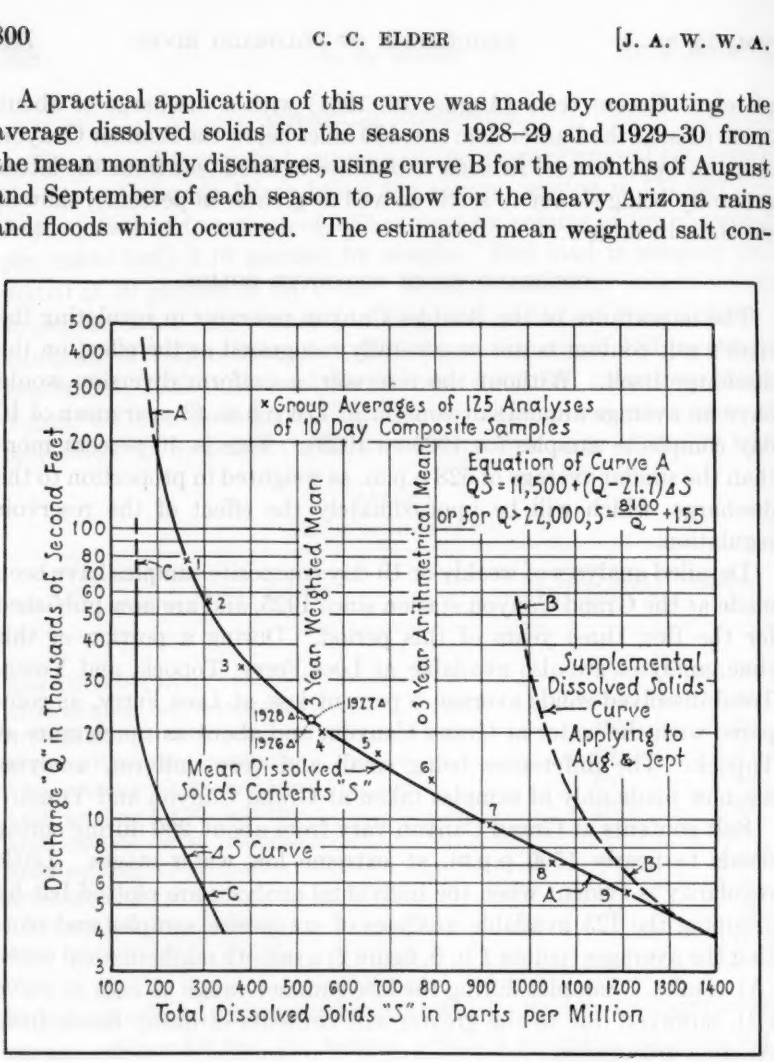


FIG. 2. COLORADO RIVER ABOVE BOULDER CANYON (GRAND CANYON GAGING STATION). DISCHARGE—DISSOLVED SOLIDS CONTENTS RELATION CURVES. DATA FROM U. S. G. S. WATER SUPPLY PAPERS 596 AND 636. PERIOD OF 1925–1928

tents were 547 and 631 p.p.m., respectively, which combined with the three earlier years, make a 5-year average of 550 p.p.m. Preliminary data obtained subsequently from the United States Geological Survey indicate mean residues after evaporation of 579 and 645 p.p.m., respectively, for the 2 recent years, which correspond to about 555

and 621 p.p.m, respectively, of total dissolved solids. These values likewise give a 5-year mean of 550 p.p.m.

Mean monthly discharges, as measured at Grand Canyon from 1922 to 1925 and estimated from measurements at other gaging stations back to 1899, were used with the salt curves of figure 2 to estimate dissolved solids for the period of record. Combined with the recent years of measured dissolved solids, the mean for the 33-year period, 1899 to 1931, is 515 p.p.m.

Quoting from U.S.G.S. Water Supply Paper 596-B, (p. 36):

> Because the composite samples for analysis were made from equal daily samples, the analyses themselves do not represent accurately the water that would be found in a reservoir containing the whole flow of the river for the period covered by an individual analysis. The error due to this effect is not great, but its tendency is to show more dissolved mineral matter than would be found in the water of a reservoir storing the whole flow of the river for a year.

This error is negligible during many 10-day periods when the discharge of the river happens to be nearly uniform. It is not compensating, however, but is always in the same direction of indicating too large a salt content. For the period July 1 to 10, 1927, the composite sample gave a salt content of 417 p.p.m., with a mean discharge of 72,100 c.f.s. which varied from 117,000 to 43,800 c.f.s. By means of the curves of figure 2, it was determined that the probable salt content did not exceed 392 p.p.m., or 6 percent less than the observed for the period's composite sample.

This correction is probably not more than 2 to 3 percent as an annual average, however, and will be practically offset in the future by the effect of evaporation from Boulder Canyon reservoir, which will increase the average dissolved solids of Colorado River water by about 4 percent initially and perhaps by 5 percent ultimately. Other future factors, such as the much discussed Virgin Valley salt beds, have been carefully investigated and concluded by all experienced engineers, geologists, etc. to be absolutely negligible.

To complete the salt story, the 3-year average total hardness is 263 p.p.m., corresponding to the observed total dissolved solids of 528 p.p.m. Chlorine averges 52 p.p.m. so that sodium chloride does not exceed 86 p.p.m., on the average, and softening will therefore be possible, satisfactory and efficient, if or when found desirable. Boron, another item of great importance, is not referred to in the regular analyses by the United States Geological Survey, but has been de-

termined by the Riverside Citrus Experiment Station of the United States Department of Agriculture and averages 0.18 p.p.m. or far below the danger point of 0.5 to 1 p.p.m.

## CONCLUSIONS

Regulation by storage will change the Colorado River from a menacing liability to one of the greatest and most important assets of the Southwest. The water supply will be made dependable and the utilizable portion improved as to quality and increased several times in quantity. Power, though an incidental factor, will repay the cost of the project and contribute its own additional benefits to the region. Thus considered from a broad viewpoint, Colorado River regulation is clearly one of those rare bargains that aids every one to some degree and damages no one. The long delay in its accomplishment was due not to doubt as to its necessity and desirability, but to minor questions as to detail of method and the difficulty of fixing the exact distribution of the anticipated benefits.

(*Presented before the California Section Meeting, October 28, 1931.*)

# WATER PRODUCTION MEASUREMENT METHODS

By L. Standish Hall

(*Chief Hydrographer, East Bay Municipal Utility District, Oakland, Calif.*)

Production of water for municipal supply comes from two sources —ground water and surface water. The ground water supply is from wells or springs. The measurement of the quantity of water derived from such a source presents no unusual problems, the total flow being measured either by Venturi meters or by the ordinary type of piston or disc meters. The second source of supply is surface run-off from streams. Surface water is obtained either by direct diversion into a pipe line, flume or ditch, or by collection of run-off in an impounding reservoir. Many methods are possible for the measurement of surface run-off and difficulties are frequently encountered in the measurement of such a source of supply.

Where an impounding reservoir is of sufficient size so as to control practically the entire flow of the stream (wastage over the spillways occurring only in occasional years) the run-off can be measured by the rise of the water surface in the reservoir. This method requires an accurate survey of the capacity of the reservoir. Since reservoirs are ordinarily subject to silting, re-surveying of the capacity must be made from time to time. An accurate determination of the draft must also be made, preferably by a Venturi meter or weir. The evaporation from the surface of the reservoir must be determined from the evaporation of land or floating pans at the reservoir site. When wastage occurs from the reservoir it must be measured by a weir or by stream gaging in the channel below the reservoir. If due precaution is taken the run-off can be measured by this method within an accuracy of 5 percent.

Where the rise and fall of the water surface of the reservoir is secured by a water stage register, considerable inaccuracy in the record may occur if the float cord is of twisted bronze wires having a hemp core. On such registers the float cord should have a wire strand core.[1]

[1] "Improving the Accuracy of Instruments," by L. Standish Hall, Civil Engineering, September, 1931.

In the event that the water is diverted from an impounding reservoir or directly from a stream into a pipe line, the flow can be measured by a Venturi meter installed in the pipe or by measuring the flow over a weir at an aeration basin. Water diverted into an open ditch or flume directly from the stream, can be measured by a weir. In order to secure accurate results by such measurements the water must be free from sand or debris or else a sand trap should be installed above the weir to remove such material. On streams which carry such large quantities of sand and debris as to require frequent cleaning of the sand trap, the use of the Parshall Venturi Flume will yield more accurate results.[2] The principle upon which the Parshall Venturi Flume operates is the insertion in the stream channel of a contraction which causes a drop in the water surface. In large canals with flat grades the use of a Venturi Fume of the Parshall type will result in too great loss of head. The same effect can be produced, however, by raising the bottom of the canal on a uniform slope causing the contraction to be effected in a vertical direction rather than in a horizontal direction.

Where headgates are installed in the canal or flume at the point of diversion, it is possible to measure the amount of diversion by rating the headgates. This requires a record of the level of the water in the stream above the headgates and in the ditch below the headgates. A record of headgate opening must also be kept. The rating of the headgates can be best accomplished by measurement of the flow in the canal with a current meter.

In some canals having very flat grades, it is impossible to secure accurate results at certain stages of flow due to the low velocity in the canal. Where such conditions prevail a very accurate measurement of the discharge can be made by rod floats. The rod float measurement should be taken in a regular section of the channel where it is possible to run the floats within 3 to 6 inches of the bottom of the channel. The observed velocities of the rod floats must be reduced to the true velocity of the water by correction formulas. Parker[3] has found that the correction formula derived by Francis from tests in a wood flume and usually quoted, is inaccurate when the measurements are made in earthern channels. It would appear that the amount of correction varies with the roughness of the channel.

[2] "Improved Venturi Flume," Ralph L. Parshall, Trans., Am. Soc. C. E., 89, page 841.

[3] "The Control of Water," Philip à Morley Parker, page 61.

Where diversions are made from a flowing stream it is frequently necessary to measure not only the amount of the diversion but the total flow of the stream in order to satisfy the rights of other appropriators upon the water course.

The measurement of large quantities of water in natural water courses must be done by current meters. At all modern stream gaging stations a continuous record of the gage height is secured by water stage recorder. The use of float cords having solid wire centers, previously referred to, is equally applicable to recorders at stream gaging stations. The instrument is usually housed in a shelter located on the bank of the stream and the float well connected to the stream channel by one or more pipes. Two gages are used, one being a staff or slope gage placed directly in the stream and the other a staff gage located inside the float well. The recorder is set to the reading of the inside or well gage. Due to difficulty of accurate reading of a staff gage, better results can be secured by setting the recorder to the reading of a hook or tape gage. The tape gage consists of a stainless steel tape passing over a pulley well located on the instrument shelf. One end of the tape is fastened to a float and the other end to a counter weight. The reading of the gage is at an indicator on the support of the pulley wheel. A comparison of the readings of the instrument and of the gage should be made at least weekly and, if possible, more frequently. Where such comparisons are not made frequently, considerable error may occur in interpreting the recorder record due to float cord errors, instrument reversals (with continuous water stage recorders) and paper shrinkage. Check made in many instances on the reading of the instrument and of the gage, following a rise in stage of several feet, usually shows that the instrument registers less than the true gage height. The reverse is, of course, true after a fall in stage. This under-registration of the gage height change is the result of small kinks which have been allowed to form in the float cord preventing it from resting snugly in the bottom of the groove of the float wheel.

On many western streams carrying large quantities of sand, difficulty is experienced in keeping clear the intake pipes between the stream and the float well. A complete stoppage of the intake pipe can usually be readily detected either from the behavior of the recorder or from a comparison of the inside and outside gages. Since the stoppage of the pipes generally occurs during high stages of the river, the loss of this portion of the record is quite annoying. A par-

tial stoppage of the intake pipe may also occur, allowing the water in the float well to continue to fluctuate with the river; but on rising stages the gage in the well will be lower than the river, and on falling stages, higher. Stoppages of this nature are sometimes difficult to detect and the recorder will continue to furnish an erroneous record over a long period of time. Where such conditions exist on a stream, they can be corrected by the installation of a flushing tank on the intake pipe. Such a tank, having a capacity of 30 gallons, is placed in the recorder shelter below the instrument shelf. The tank is connected to the lower intake pipe on the inside of the float well. A three-way valve is installed at this point, permitting communication from the river either to the float well or the flushing tank. In order to flush the intake pipe, the opening to the float well is closed and the contents of the flushing tank discharged into the river. This method has the advantage of facility of operation at all stages of the river and is the best solution yet devised for this troublesome problem. On streams carrying great quantities of silt and sediment it is often necessary to install a silt trap in the intake pipe between the river and the float well.

It is also desirable to secure levels at each foot mark on both inside and outside gages in order to correct the reading of the outer gage in case of settlement of either. Slope gages are most troublesome in this regard because of the possibility of unequal settlement of the ends of the gage.

Stream gagings are usually made, in the United States, with the Price type meter. Until recently little had been done to determine the relative accuracy of the various types of current meters. The laboratory test by Yarnell and Nagler[4] indicate that in turbulent water the Price type meter over-registered while meters of the Hoff, Ott, and Haskell type under-registered.

The Price meter is of the cup type in which the wheel rotates about a vertical axis while the other meters are of the screw type in which the wheel or propeller rotates about a horizontal axis ordinarily held in the direction of the flow of the stream. In flowing water in natural channels, due to both the frictional resistance and to internal forces, volumes of water are detached continually from the boundaries and revolving form eddies traversing the fluid in all directions and sliding with finite velocities against those surrounding them. When a meter is held in a flowing stream it is acted upon during successive instances

[4] "Effect of Turbulence on the Registration of Current Meters," by David L. Yarnell and Floyd A. Nagler, Proc., Am. Soc. C. E., December, 1929.

by different stream filaments which may be flowing in various directions and at various speeds. The difficulty, therefore, in the measurement of flowing water by means of a current meter is due to the failure of duplicating conditions under which the instrument is calibrated with conditions under which it is used. As stated, the two types of meter in general use, the cup type and the screw type, have opposite characteristics when used in running water. That is, the first type of meter is accelerated by obliquity or turbulence, and the second type is retarded by oblique or turbulent flow. The degree of over-registration or under-registration has been determined by some investigators by still water rating of the various types of meters, with the meters turned at successive angles or obliquity to the motion. A weighted mean of the quantities indicated by the two types of meters can be taken as the true quantity of water flowing in a stream.

Current meter measurements made from a rod are more accurate than those taken with the meter at cable suspension. At high velocities the turbulence of the water will cause the meter supported from a cable to sway from side to side accentuating the over-registration or under-registration of the two types of meters. The normal turbulence from flowing water must be distinguished from excessive turbulence or eddying. Excessive turbulence is caused by large obstructions in the stream such as bridge piers or large submerged rocks or by a sudden change in the cross-section of the stream channel. An expansion of the cross-section occurs to a greater or less degree at all gagings taken from the stream side of a bridge. If a bridge having other than a clear span is to be used for gaging, it is preferable to make the gagings from the up-stream side using a boom to keep the meter clear of the bridge piers.

In general, more accurate measurements can be secured where the meter is used from a cable car suspended above the stream channel. In locating a cable section, a survey should first be made of the cross-section both above and below the proposed site in order to secure a section free from excessive turbulence. If large floods unfavorably change the bottom or banks, nothing remains but to remove the cable to a new location if accurate gagings are to be continued. The error in measurements with rod support, due to meter characteristics, usually does not exceed 5 percent of the flow; error with cable support may be as great as 20 percent of the flow.

In many cases it is necessary to make accurate measurements of the flow of water in a stream channel from which diversions are made for

municipal water supply, in order to determine the amount of seepage occurring from the stream and replenishing wells located in valleys below the point of diversion. Measurement of the flow must be made at two points in order to determine the loss from the stream channel. The upper point of measurement is generally selected in the foothills where the streams debouch from the mountains into relatively level valleys. The second point of measurement is further out in the valley floor where the slope of the stream is less than near the base of the foothills. Since the over-registration of the Price meter increases with turbulence which in turn increases with the velocity of the water, where measurements are made for the purpose of determining seepage loss, the over-registration of the Price meter at the up-stream station where velocities are greater, will exceed those recorded by the meter at the down-stream station. Measurements taken even with great care on such streams, using the Price type meter alone, would indicate a greater channel loss than actually occurs.

The accuracy of results obtained from gagings at even reasonably good sections may be affected by the method used in taking current meter readings for the averaging of velocities in a vertical plane. The rules described by B. F. Groat[5] for averaging the velocities in the vertical, can be used to very good advantage. The superiority of the 0.15, 0.50, and 0.85 depths to the other three point methods of securing the velocities in the vertical has been demonstrated both theoretically and from numerous gagings.

Vertical velocity curves are of great assistance in the computation of discharges in the office by indicating the characteristics of the measuring section. Erratic curves are due to turbulence. Slight curvature of the channel, unevenness of the bottom or uniformly expanding or contracting cross-sections above the gaging station will produce velocity curves uniform in shape by varying from the normal parabolic form. Conditions may exist which will produce a vertical velocity curve with the maximum velocity at 0.6 or 0.8 of the depth.

The effect of variable water surface slope on the discharge relation affects the results on streams more frequently than is ordinarily appreciated. When the change in slope is quite marked this condition is readily identified.[6] However, in many instances the effect of varia-

[5] Discussion by B. F. Groat, Proc., Am. Soc. C. E., November, 1930, of paper "Effect of Turbulence on the Registration of Current Meters."

[6] "A Discharge Diagram for Uniform Flow in Open Channels," by Murray Blanchard, Proc., Am. Soc. C. E., January, 1931.

tion in slope is so slight that it is confused with a shift in control. In cases where variable surface slope is combined with a shifting control the separation of the two effects is often quite difficult. The control is affected on a stream when the water surface proceeding in the direction of flow changes from a flatter to a steeper slope. Some controls are so slight that they are drowned out when higher stages are reached and the condition of varying surface slope is introduced. In order to determine whether or not such a condition exists, gagings should be made on both rising and falling stages of the stream.

The accurate measurement of flowing water is very difficult and unless the hydrographer is continually on guard, large errors will creep into the records. When carelessly used, errors are possible even with such precise measuring devices as Venturi meters and weirs. In measuring flow in open channels, the hydrographer or observer in the field should make complete notes of any conditions at the gaging stations affecting the relation between gage height and discharge, in order that the engineer in the office may intelligently interpret the records.

*(Presented before the California Section meeting, October 26, 1931.)*

# MODERN SERVICE INSTALLATIONS

By H. A. Harris

*(Operating Engineer, California Water Service Company, San Francisco, Calif.)*

Among the first services of record is the well in Jerusalem where the women came with their earthen jugs and filled them, and climbed the stairs balancing the jugs upon their heads. This service is still in use today, the only difference being that five gallon oil cans have replaced the earthen jugs. We also had the old town pump in early American communities where all of the inhabitants came to get their water supply. A very unique water service was in vogue in several western mining towns. This consisted of a string of ten burros each carrying two water bags. Each consumer had a water barrel which the owner of the system agreed to keep filled for $1 per month. I assume that this formed a basis for our present minimum monthly charge. The owners investment per service was quite low compared to our investment in Stockton of about $150 per consumer.

It was therefore quite a step forward to the time when individual services were carried into each home.

Many materials have been used in services in the past several centuries. Among these were, wood pipe made from bored logs, lead pipe and wrought iron pipe.

These materials had a great many objections and so we find that when wrought steel pipe was developed it was quite universally adopted due to the fact that it was relatively cheap and overcame the difficulty experienced with lead pipe, namely, lead poisoning.

In order to make steel more resistant to corrosion, the galvanizing process was developed and served very well.

It is safe to say that by far the majority of the services now in the ground are of galvanized steel.

When our company first took over its properties in 1926, we made a study of our services and found that all the services, except a very few, were of galvanized or black steel pipe. In our Petaluma plant, we had a few hundred services of genuine wrought iron pipe.

We began at once to gather some data relative to the life of our services. We found that in some localities there were services 30 years old that were in very good condition and that in other localities we were replacing these services within 18 to 36 months after their installation. We also found that in some localities where the pipe suffered very little from external corrosion it was badly tuberculated on the inside and often so filled with growth on the inside that its carrying capacity was reduced 25 to 50 percent.

Prior to this time steel service pipe with inner lining was on the market. To my knowledge, at least two linings were used, cement and lead. Seamless copper tubing also was being used somewhat.

Due to the above troubles that we were experiencing with steel service pipe and a growing interest in lined pipe and copper tubing, it was decided to try the newer materials. At the beginning of 1928 we decided to make all our service installations of $\frac{3}{4}$- and 1-inch size with either lead lined galvanized steel pipe or seamless copper tubing in approximately equal quantities. At the same time it was decided to make all services over 1 inch in size with cast iron pipe. Pipe with precalked lead joints were to be used in the $1\frac{1}{4}$- and 2-inch sizes.

As our territory of operations covers practically the entire Pacific Coast from Mt. Vernon, Washington, 70 miles north of Seattle, to Redondo Beach, 20 miles south of Los Angeles, we had an excellent opportunity to make a thorough trial of these materials under all kinds of soil and water conditions. We have well supplies with comparatively hard water and gravity supplies with very soft waters. Our collective purchasing power also made it possible to purchase in carload lots thereby getting the best market price in making our trial installations.

In order to assure absolutely uniform installation throughout the system, our Engineering Department prepared a set of drawings showing the standard method to be followed for each material.

When these materials were first sent out to our plants, we found a tendency for many of our service men to favor the lead lined steel pipe over the copper tubing. Upon investigation, I found this was because it cut, coupled and handled exactly the same as the steel pipe, which they had been using, whereas, the copper tubing had to be handled quite differently. We insisted upon the use of equal quantities of both materials, and found that, after installation of large quantities of both materials, most of the men preferred to handle the copper. This was largely due to the fact that it came in coils, did not have to be threaded and few fittings were required.

Another objection which came up in the beginning was the construction foremen's belief that the copper tubing could not be installed by pushing or hydraulic methods. On first thought this seems reasonable enough, but I will explain in detail later several methods of accomplishing this.

After two years trial of lead lined steel pipe and copper tubing, we decided that for our use the latter was the most satisfactory. The copper tubing is easier to handle, the labor cost is less, very few fittings are required, and it is equally resistant to corrosion from the inside and the outside. One very serious objection we had to the lead lined pipe was that much of this pipe was not lined with a uniform thickness of material.

I am going to devote the greater part of this paper to details of copper tubing installations, as I feel that this will prove the most interesting and probably the least familiar to a majority of you.

## COPPER TUBING INSTALLATIONS

The number of copper services we have installed in each of our plants is shown in table 1.

Table 1 shows 5935 copper services installed. We have in the system 86,300 services up to and including 1 inch in size and 4200 services over 1 inch in size of which 500 are of cast iron.

Table 1 shows no copper services in our penninsula properties. We began operation of these properties on July 17, 1931, but have now started the use of copper.

### *Installation method*

As stated above, we sent to all our plants drawings showing standard service installations and also standard specifications, including a list of materials which are carried in stock in our central warehouse. However, in order to take advantage of the initiative of our construction foremen, we left open the exact method of making the installation. The results were that we find slightly different methods in use in various plants due to local conditions, etc.

Short services are practically always installed in hand dug ditch from main to property line. Long services are bored regardless of whether or not the street is paved.

Copper tubing must be correctly used in order to get the full benefit of its advantages. I wish to call here particular attention to the simple preparation of the material. A coil of tubing is taken and

enough measured off and cut to make the service. The piece should be 3 or 4 inches longer than the measured distance. The end of the tubing is then reamed and flanged and the male coupling is flanged onto the end at the curb cock and the female coupling at the end of

TABLE 1

*Number of copper services installed*

| PLANT | COPPER SERVICES |
|---|---|
| Bakersfield | 659 |
| Belvedere (East Los Angeles) | 1,598 |
| Chico | 89 |
| Contra Costa | 421 |
| Dixon | 20 |
| Hanford | 73 |
| Hermosa-Redondo | 575 |
| Hillsborough | 0 |
| Livermore | 176 |
| Lomita Park | 0 |
| Los Altos | 0 |
| Marysville | 16 |
| Oroville | 98 |
| Petaluma | 62 |
| Redding | 101 |
| San Carlos | 0 |
| San Mateo | 0 |
| South San Francisco | 0 |
| Stockton | 977 |
| Willows | 24 |
| Visalia | 100 |
| Burlington, Washington | 18 |
| Hillsboro, Oregon | 68 |
| Marshfield, Oregon | 421 |
| Mt. Vernon, Washington | 59 |
| Salem, Oregon | 192 |
| Sedro Woolley, Washington | 48 |
| Vancouver, Washington | 140 |
| Total | 5,935 |

the corporation cock. The straight connectors or the 90° bend connectors are used as required, dependent upon the relative depth of service, curb cock, and main.

In the beginning we ran into difficulty in making a proper bend in the tubing. After trying various devices we found a bending spring

previously used for bending lead pipe to be the most simple and satisfactory.

The first instructions in the use of copper tubing should always be given by some one who knows in order that correct method will be used from the start.

Detailed explanations of several methods used are given as follows:

*Method 1.* A very small excavation is made at consumers connection in order properly to connect service pipe to meter. A larger excavation is made at the main large enough to install boring machine, approximately 2 feet wide by 8 feet long. The main is then tapped with a wet tap machine and the boring machine installed and connected with water. After the boring is completed the machine is removed and a coil of copper tubing is unrolled as it is forced through the bore. After tubing is through to the service it is connected to tap in main and also at curb.

*Method 2.* This method is for use where boring machine is not available. The main is tapped as before. An iron pipe thread to hose thread coupling is connected to the corporation cock and an ordinary garden hose is connected to the coupling. A copper to iron pipe coupling is flanged to a piece of copper tubing, and the other end of the hose connected to this by use of an iron pipe to hose thead coupling. A hole is then started in the bank of the hole, dug for the tap, with an iron bar. The open end of the copper tubing is then started in this hole with the water turned on. By jabbing process the tubing is forced through to the service connection. This method has been successfully used to hydraulic 30 to 40 feet within 6 to 12 inches of the point set. After the tubing is through the hose couplings are disconnected and the tubing connected to the corporation cock and curb cock as before. The only troubles experienced with this method are where a rock or other solid substance is struck or where very sandy soil is encountered. Of course, where a rock is struck it is necessary to dig down and remove. Very sandy soil will bind the pipe so that it cannot be moved in either direction. When this happens it is necessary to dig out the end and begin hydraulic process again from this point. A slight variation from this method consists in putting a steel pipe nipple about 12 inches long on the forward end of the copper tubing.

*Method 3.* A cut 10 feet long by 18 inches wide is made at the main to accommodate the pipe jack and another about 2 feet by 2 feet is made at the curb. The tap at the main is then made. The

jack is then set in the hole and old 2-inch screw pipe cut in lengths about 7.5 feet long are forced through with the jack. The first piece of pipe forced through is plugged to keep dirt out. This 2-inch pipe serves as a protector for the copper tubing. A bending spring is then inserted in the end of the copper to keep out dirt and the copper tubing is pushed through the 2-inch pipe to the hole at the meter location. The tubing is then bent upward to the meter level and connections made as previously described.

*Method 4.* This method is similar to method 1 except that a steel pipe a size larger than the copper tubing is pushed through. When this reaches the end of the curb the copper tubing is fastened to that end and the steel pipe is then pulled back through and the copper tubing pulled through behind it. The steel pipe is uncoupled and taken out as it comes back. A slight variation of this method is to push the steel pipe through and pull it out and run the copper tubing through this bore. Connection then made, as previously described.

*Method 5.* This method is used when an old service is to be replaced with copper. In this instance the old service pipe is cut off and pulled out with the pipe jack and the new copper service is pushed through the hole left by the old pipe. Connections are then made as described in other methods.

I said in the early part of the paper that we found some steel services 30 years old, which were in excellent condition, and many of you will wonder why we would use copper in such places. One reason is that it is more satisfactory to have a uniform standard; a careful study and soil analysis would be required to determine where steel would be satisfactory; we believe that under any condition copper will out last steel sufficiently long to pay for additional cost. However, this will be proved by actual life of service.

In all of the above methods the service is installed to a depth of about 24 inches.

In case of services over 30 feet in length it is our practice to install a 1-inch service and split it into two $\frac{3}{4}$-inch services at the curb line.

## CAST IRON INSTALLATION

We make all our cast iron service installations under pavement by boring and when not under pavement in open cut. The bore is made by use of boring tool made of a short piece of steel pipe slightly larger than the bell of the cast iron pipe. This pipe has two teeth on it which act as auger. The pipe is turned by means of chain tongs

and the bore is put clear through to the service by adding on additional sections of steel pipe. When the bore is completed the boring pipe is removed by hooking onto it with chain tongs and a truck. The cast iron pipe is then run through the bore. For long bores we use 20 feet lengths of cast iron pipe.

### COSTS

The cost of the copper service is about 20 per cent more than for galvanized steel. However, we believe that its longer life and freedom from tuberculation will justify the extra cost many times.

Cost of $\frac{3}{4}$ inch copper service 20 feet long:

| | *dollars* |
|---|---|
| Corporation cock $\frac{5}{8}$ by $\frac{3}{4}$ inch | 0.45 |
| 20 feet $\frac{3}{4}$ inch tubing | 3.25 |
| Couplings and ell | 0.70 |
| Curb cock, type "H" | 0.60 |
| Labor | 6.00 |
| Total | 11.00 |

Cost of 1 inch copper service—20 feet long:

| | |
|---|---|
| Corporation cock $\frac{3}{4}$ inch by 1 inch | 0.50 |
| 20 feet 1 inch tubing | 4.30 |
| Coupling and ell | 1.10 |
| Curb cock type "H" | 0.90 |
| Labor | 6.00 |
| Total | 12.80 |

Cost of $1\frac{1}{4}$ inch cast iron service—20 feet long:

| | |
|---|---|
| Bell brace | 1.22 |
| Corporation cock 1 inch by $1\frac{1}{4}$ inches | 0.78 |
| 20 feet $1\frac{1}{4}$ inches C. I. pipe precalked | 6.45 |
| $1\frac{1}{4}$ inches by 12 inches C. I. nipple | 0.70 |
| Curb cock type "H" | 1.80 |
| Labor | 9.00 |
| Total | 19.95 |

Cost of 2 inch cast iron service—20 feet long:

| | |
|---|---|
| Bell brace | 1.75 |
| Corporation cock $1\frac{1}{2}$ inches by 2 inches | 2.35 |
| 20 feet by 2 inches C. I. pipe precalked | 7.70 |
| 2 inches by 12 inches C. I. nipple | 0.80 |
| 2 inches brass G. V | 3.45 |
| Labor | 12.00 |
| Total | 28.05 |

We have not as yet decided which method of making the installation is the most economical or if any one of the methods would meet all conditions. Method 2, which requires no boring machine or boring pipe is, I believe, the best where conditions will permit its use.

After three and one half years use of copper tubing and cast iron pipe for all services, we believe that these are the best and most modern materials now available for making service installations.

It was our thought that all water departments and municipalities are looking for improved methods and that a somewhat detailed account of this, the largest experiment in the use of copper service pipe in California would be interesting.

(*Presented before the California Section meeting, October 30, 1931.*)

# CORROSION FOLLOWING WATER PURIFICATION PROCESSES

By Chester A. Smith
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The dictionary definition of corrosion is—"diminish gradually by chemical action." To one not acquainted with corrosion troubles, this definition would create the impression that corrosion is similar to erosion, namely, the mechanical process of wearing away of the interior surface of a pipe line as by the action of water carrying sand and grit at high velocities. While corrosion actually diminishes the thickness of the metal in the pipes, it also builds up a scale of iron rust, tubercles and other similar deposits of chemical and organic compositions, thereby decreasing the inside area of the pipes, and by increasing the roughness coefficient greatly decreases the carrying capacity of the pipe system. Thus corrosion also causes incrustation, which is a term commonly used for the action of the deposition of scale-forming minerals contained in a water supply, or by chemicals added to the water in the process of water purification.

The annual losses due to corrosion of water mains are enormous. The total loss is not only in the cost of replacement of pipe lines, but also includes the accumulation of numerous losses incident to corrosion, such as repairing of leaks, the property damage due to leaks, additional power required to overcome increased frictional resistance, red water troubles causing damage to clothes, staining of bath-room fixtures and other actual economic losses. The total annual economic loss due to corrosion in water pipes has been estimated as ranging from fifty to one hundred million dollars.

With such an amazing figure of actual economic loss and with all the troubles and complaints arising from corrosion, naturally the question is asked: Why have not measures been taken to prevent corrosion or to eliminate the cause? Some of the apparent major reasons are offered: Indifference on the part of the waterworks operator, reliance on the purchasing of pipe with protective linings supposed to be corrosive-proof, and the confusion caused by the

various hypotheses advanced as to the causes of corrosion and the ways in which corrosion takes place.

The first hypothesis regarding corrosion was simply oxidation, or the rusting of iron metals. Then came hypotheses embracing the natural solubility of iron in water, the presence of free or half-bound carbon dioxide, acidity, electro-chemical action, and the biological action of certain bacteria. Many of these were expounded with long formulas of chemical reactions and in terms too technical to be readily comprehended by the average waterworks superintendent and operator. Hence the general impression was created that the application of corrective measures was theoretical and not practical.

Corrosion troubles were emphasized following water purification processes, particularly where the untreated water was comparatively soft. The appearance of "red water" and its attendant complaints brought about the necessity for studying the cause and the application of preventive measures. This has stimulated the study of corrosion and its control beyond the mere prevention of "red water." Severe corrosive action is seldom encountered where water supplies contain high carbonate hardness, either with purification or following filtration or water softening processes.

The process of clarification of a turbid water by sedimentation and filtration usually depends largely upon the formation of a floc produced by a chemical reaction. Likewise, the removal of color depends upon the absorption or bleaching powers of certain chemical compounds. The process of water softening by the addition of lime and soda ash is dependent upon the changing of chemical combinations existing in the raw water, from a state of solubility to insoluble compounds which will precipitate. Thus chemical balances must be preserved in these processes or there will be formed, or left to remain in the water, certain compounds of a caustic or corrosive nature.

For example, aluminum sulphate ($Al_2(SO_4)_3$) has been and is still widely used as a coagulant in water purification processes. The chemical formula for the desired alum floc is aluminum hydroxide ($Al_2(OH)_6$). In order to produce this floc other mineral combinations must be applied either as existing in the water as natural alkalinity, or lime or soda ash must be added to produce the necessary reactions. Free carbon dioxide ($CO_2$) is one of the by-products unless there is an excess of lime to combine with or to absorb this corrosive element. Some authorities state that carbon dioxide is not a direct cause of corrosion, but is an indirect factor by the indirect method of dissolving the protective coatings, especially the calcium carbonate film on the

iron. Thus a water with a high $CO_2$ content would eventually dissolve the cement lining of iron pipe that is now manufactured and used as a method of preventing pipe tuberculation and corrosion.

In opposition to corrosive troubles following water purification, incrustation of pipe lines by the deposition of excess lime used in water softening may be briefly mentioned here as an added necessity for maintaining chemical balance in water purification processes. The more modern water softening plants are now recarbonating, or adding carbon dioxide to prevent excessive incrustation of filter sand and of the pipes in the distribution system.

Numerous instances can be cited where water purification processes have increased corrosion, generally, as stated hereinbefore, where the raw water to be purified is soft or low in alkalinity, such as the supplies found in Eastern States and in the surface supplies of the Southern States. "Red water" has been the warning red flag, and it has usually been followed by the use of a corrective method. In general, the addition of lime has been found to be the most efficient and economical method of stopping "red water" troubles and the retarding or stopping of corrosion.

Although there may be special cases with certain water supplies that will require the technique of a special water chemist to determine the exact cause of corrosion and the most economical and efficient method of correction, in general the pH control and calcium carbonate control will guide the operator in retarding or preventing corrosion. If a pH of 7.5 to 8.5 is maintained, little, if any, corrosion will occur following water purification, or with an untreated corrosive supply. Again, as a general rule a water just saturated with calcium carbonate is the most desirable chemical balance to prevent corrosion, except with soft waters, when it should be slightly supersaturated in order to deposit a light protective film on the metal. However, this supersaturation must be carefully watched; otherwise there is the danger of producing a caustic condition.

Mr. Charles P. Hoover, Chemist, Columbus, Ohio, states that if the "calcium carbonate content of the water is, say something less than 20 p.p.m., then it is necessary, if corrosion is to be prevented, to build up the calcium carbonate content." The next step is to adjust the pH value to the proper point which Hoover suggests by the use of soda ash, and then test for the calcium carbonate ratio of saturation.

Mr. John R. Baylis, Physical Chemist, Bureau of Engineering, Chicago, Illinois, in a recent article says: "Where the water has less than 25 p.p.m. of calcium carbonate, lime should be used for the

protection from corrosion, and where there is more than this amount either lime or soda may be used, although lime is much cheaper than soda." In conclusion of the article Baylis makes the following statement: "Corrosion prevention by the treatment of the water has been demonstrated to be practical and economical." This being true, then it seems all corrosive waters should be treated.

In conclusion, it may be stated that practically all potable waters, or waters that can be rendered potable by purification processes, which are used for public water supplies are more or less corrosive. Corrosion troubles are usually of small concern where waters have high carbonate hardness content or with waters that are softened by the use of lime and soda ash. As the amount of alkalinity or carbonates becomes less or approaches the chemical balance, the corrosive properties of the natural water usually increase and water treatment processes may overthrow this balance and suddenly increase the corrosive elements or properties of the water. "Red water" is a sure indication of this increased intensity of corrosion, although the water may have been doing its damage in pitting the pipe system, building up rust and tubercle incrustation before the "red flag" was waved by the installation of a water purification process. It may have occurred in some cases where an erroneous idea was created to the effect that the purification process and its use of "*chemicals*" was the sole cause of "red water" and corrosion. However, in general, the purification process has brought about a better understanding of corrosion problems and the means for stopping or retarding same.

It has been demonstrated in a number of cases that by a proper chemical balance, an adjustment of the pH value, and the use of some supersaturation of calcium carbonate, the interior of a pipe system can be lined with a corrosive-proof protection of carbonate film. The removing of tubercles and incrustation by mechanical scraping or cleaning methods will greatly increase the carrying capacity of the corroded pipe system, but this does not prevent corrosion and the recurrence of tuberculation unless corrective or preventive measures are taken by adjusting the proper chemical balance in the supply. This adjustment can usually be more readily made where the supply is treated by a purification process, as all the supply is concentrated at one point and laboratory facilities and chemists are available, as well as equipment for regulating the dosage of lime or other chemicals in the purification.

*(Presented before the California Section meeting, October 28, 1933.)*

# OFFICE PRACTICE IN THE WINSTON-SALEM WATER AND SEWER DEPARTMENT

By R. L. Dixon

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The Billing and Collection Office of the Water Department of Winston-Salem was taken over by the Department of Public Works on August 31, 1930. This move was taken to consolidate this office with the Department of Public Works, which controls the construction, operation and maintenance of the physical plant.

At the time of the consolidation there were 11 persons employed in this office, 5 inside handling the billing and collections and 6 outside handling the meter readings and cut-offs. Since the consolidation the Department of Public Works has constantly strived to reduce the expenditures and increase the efficiency of this office.

A few months after the consolidation the period of reading meters was changed from ten days to continuous. This enabled us to consolidate the office and water repair forces of the Department of Public Works with those of the Collection Office, thereby reducing the combined personnel by three. This was principally brought about by the elimination of duplicate work and the absorption of lost time.

The present personnel of Billing and Collection Office consists of two cashiers, two bookkeeping machine operators, one full time meter reader, and three who serve as meter readers, and cut-off men. Due to the increased work occasioned by this period through which we are passing, it has been necessary for four persons in the Administration office of the Department of Public Works to devote about twenty-five per cent of their time to this office while the four men on the Water repair force, devote approximately ten percent of their time.

To increase further the efficiency of this office we have discarded our old method of billing and bookkeeping. This method was known as the Register Plan. The forms used under this plan of billing consisted of a bill, a ledger sheet, meter card and a summary sheet.

The bill was divided into three parts, Office Copy, Receipt and Mailing Notice. It was carbon spotted and perforated so that all copies and ledger account could be made in one operation of the billing machine. The ledger sheet had forty lines each line numbered to correspond to each account. The columnar headings of the sheet provided for, Current Arrears, Account number, Cubic Feet Consumed, Water and Sewer Charges, Previous Arrears, Total, Sundries, Date Paid, Amount Paid and Rebates.

The Meter Card provided for twelve months readings and had space at the top for name, address and account number.

Our procedure under this system was to preaddress the month's bills on the Addressograph, showing, name, address and account number. Meter readings started the first of each month and continued through the twenty-fifth and were read in numerical order according to account numbers. Meter cards were turned over to the billing clerks daily. A ledger sheet was placed around the platen roller of the billing machine. A bill with the account number corresponding to that on the meter card was folded and inserted in the front feed device of the machine and lined up with the corresponding number on the ledger sheet. The bill was then made, showing reading dates, present and previous readings, water and sewer charges and total amount. Totals were taken after every five hundred bills.

These totals showed the amount of water consumed, the water charges, and the total amount of the five hundred bills. A summary sheet was put into a wide carriage adding machine and a list made of the five hundred bills and checked against the total shown for the group on the ledger sheets. The bills were then straightened and filed until the end of the month.

Payments were posted daily. Each day the collection office turned over to the bookkeeping office the office copy of all bills collected the previous day, together with an adding machine tape of the amount. Another tape of these bills was made and checked against that of the collection office. The bills were then put in numerical order and posted to the ledger. At the end of the month arrears were brought forward to the current arrears column on the ledger sheet. The ledger was then balanced in groups of five hundred accounts. After balancing the current arrears were brought forward to the previous arrears column on the new ledger and on the new bills. Bills going to individuals, or firms paying more than one bill were separated from the individual list. The mailing stub was torn from

the bills of the individual list, enclosed in an envelope, stamped, sealed and mailed. The other bills were then separated according to the individuals or firms paying them. Mailing stub torn off and mailed.

### DISADVANTAGES OF OLD SYSTEM

We found that this system had many disadvantages, of which just a few will be mentioned in order of their importance.

A great deal of time and duplication of efforts was lost in auditing bills under this plan and often resulted in nothing more than test checks.

There was no record of previous readings kept in the bookkeeping office under this system.

There was a great possibility of posting a payment to the wrong account and could only be caught on complaint.

Arrears could be forwarded to the wrong account. This type of error could not be readily caught in the office and was often never caught.

The notice being a carbon copy was often very dim and could not be read readily.

The space for the meter readings was limited on the bill and overlapped making them illegible.

To trace the history of an account it required the handling of ledgers for several months billing and a great deal of time was lost. It did not afford a ready analysis of water consumed or the number of consumers in each rate group.

### NEW SYSTEM

For many months we have been planning a system whereby the cost of mailing could be reduced and the many disadvantages of our old system of bookkeeping could be overcome without increasing our personnel.

On November 1, we installed a new billing and bookkeeping system which we believe will overcome most of the difficulties which we have encountered in this phase of public utility accounting, and that our present personnel will be able to carry on with ease.

To make this new installation it has been necessary to add to our present equipment consisting of two front feed billing machines and an Addressograph. A selector attachment for the Addressograph; six, $26\frac{3}{4}$ inch ledger trays and an Analysis machine. The cost of

this new equipment will be offset by the savings in postage this year. If the present postage rates continue in effect our savings will amount to approximately $2400.00 a year, and should it return to the old rate, this will be cut in half.

The forms necessary for this installation consists of a meter card, a bill, a postal card, a plain card, a ledger sheet, a summary sheet and an audit sheet.

The meter card is the same as the one used under the old system.

The bill is 16 by 4½ inches carbon spotted and perforated to divide it into two parts 5½ by 4½ inches each, and one 5 by 4½ inches. The center copy is the original. The one to the left is the customer's receipt and that to the right is the cut off stub. The cut off stub bears space to show the date cut off, or whether the bill was collected at the door; if collected at the door the amount and date collected and signed by the man cutting off. The cut off man is charged with the cut off stubs he takes out and must return all of them or account for the missing ones. The returned stubs are filed according to account number for future reference. Later this stub will be used as the basis of cut off charges on the account ledgers.

The Postal cards are printed in strips 22 by 3¼ inches and perforated to form four regulation size postal cards. This is designed to speed up the addressing operation. It shows the reading dates, previous and present readings, water consumed, water and sewer charges, total amount and balance brought forward.

The plain card is the same as the Postal card.

The ledger sheet is 12¼ inches square, tumble head form and provides space for three year's billing. This sheet has space at the top for the name, address, account number, and any other data necessary to the account. Sufficient space is provided at the top to take care of information necessary for a deposit system should it be decided that such a system is necessary. A deposit is not required at this time but is under consideration. The columnar headings provides for the reading dates, present and previous readings, cubic feet of water consumed, water and sewer charges, old and new balances, date of payment, amount paid, rebates and sundries.

There is one sheet for each account, which shows the history of that account for three years.

The sheet is balanced automatically after each debit and credit posting, the same as Commercial Accounts Receivable.

These sheets are filed in six trays. Five trays of 2000 accounts each and one of 3200.

The trays are broken down into groups of five hundred accounts each. Each group having a controlling account.

As new accounts are opened they will be filed in the trays according to the meter reading route. The account number will be governed by the last number in the Addressograph plate file and its position in the ledger tray. For instance, the last plate in the Addressograph file is account number 13200 and the ledger sheet is filed between account 6510 and 6511. The new account number will then be 13201 with 6510–6511 directly under it. The trays are divided between two ledger clerks who post debits and credits to the accounts and prepare the summary sheets and keep the controlling accounts in groups of five hundred.

With this ledger sheet the bookkeeping office has a permanent record of meter readings of each account

Should the previous reading on the meter card be different from the present reading of the previous month it is readily detected when the account is posted by the ledger clerk. It will facilitate the work of balancing the ledger at the end of each month because it will not be necessary to forward arrears. This work being automatically done through the month when debits and credits are posted.

The summary sheet is 9¼ inches wide by 34 inches long and provides for 125 accounts and there is space at the top for the initials of all persons handling the various phases of the billing.

In operation, this sheet is covered with a sheet of carbon paper and placed around the platen roller of the bookkeeping machine. As ledger sheets are posted all postings on each account are recorded on this sheet. These sheets are turned over at the end of each month to the Commissioner of Finance for his files.

The Audit sheet is a roll of adding machine paper approximately 4½ inches wide and is used in the analysis machine.

It has been necessary to divide our Addressograph plates into four groups, namely, the regular mailing list; the vacant list, the non mailing list and the group list. This is accomplished without disturbing the numerical sequence of the plates by inserting metal tabs in various positions in each plate. Each group has a different color tab which is inserted in the group position. The non mailing plates have the letters O.S.D., meaning outside of mail delivery, directly under the address. The group plates have the first letter of the last name or the initials of the individual or firms paying them, directly under the account number. There is no designation on the vacant

or regular list other than the tabs. Names and classification changes on the plates are made daily as such information is received.

The same front feed bookkeeping machines, that were used for the old system, are used for the ledger postings. For this type of work the front feed is far superior to the back feed.

The printer and carriage of the Analysis machine is especially designed for the new system inaugurated. It will make the Postal card and bill in triplicate through carbon spot simultaneously, giving original printings on the original copy of the bill and on the postal card. The original printings will insure us against dim figures on the notice, and also against overlapping of meter readings. The machine has twenty-one accumulators. As a by-product of the billing operation an analysis of the water consumed by rates and the number of customers in each rate group is obtained as is also the total of the present and previous readings, the water and sewer charges and the total charges together with the number of accounts making up the totals. With this analysis we are enabled to audit the billing of each ledger and the previous readings. We are also enabled to readily determine the number of consumers and the amount of water consumed in each rate group.

This information is important for rate making and should be on hand at all times to show the trend of consumption by rates. Rates should be changed voluntarily and periodically according to trend of consumption. The total amount of water consumed should be on hand at all times to compare with the amount pumped. With this comparison, the percentage of waste water can be determined monthly. Should this percentage increase materially in any month steps can be taken to locate the trouble.

### PROCEDURE

All bills for the month are pre-addressed, each portion bearing all of the information on the Addressograph plate. The Postal cards are then addressed, this is accomplished by setting the selector attachment to print all plates with tabs for the regular list. After the Postal cards are addressed the plates are again run through the machine, this time the plain cards are addressed, the selector attachment being set to print the tabs for the vacant, non mailing and group list. The addressed bills, postal cards and plain cards are then sent to the bookkeeping office. To address our list of 13200 accounts the services of one man for three days is required.

The meters are read continuously as has been done for the past two years, and meter cards turned over to the bookkeeping office.

The date of reading is set in the bookkeeping machine and posted to the ledger at the same time as the present reading. The previous reading is automatically subtracted by the machine and a total taken which is the cubic feet of water consumed for the reading period. From a predetermined chart the water and sewer charges are posted. The old balance is picked up and a total is taken which is the new balance. All old balances on vacant accounts are picked up each month. The bookkeeping machine is cleared after every five hundred accounts, totals being shown on the summary sheet. The accumulations show the total water consumed and old and new balances for the group. The old balances accumulated, are checked against the balance shown on the control card for the group and establishes the proof that old balances have been picked up correctly. The difference between the old and new balances is the amount of billing for the group. These figures are posted to the individual controlling account and to the main control account.

The summary sheet which is a by-product of this operation is then turned over to the department accountant.

The ledger sheets are then taken to the analysis machine. On one side of the machine are the addressed bills, postal cards and plain cards stacked in numerical order according to account number. On the other side space is provided for the ledger sheets and rack for the completed bills and cards. This rack is divided to provide for Regular List. Vacant List and Group List. The bill is folded and inserted in the upper printing carriage of the machine while the postal card to match the bill is inserted in the lower.

The present and previous readings and dates, the amount consumed, the water and sewer charges are copied from ledger sheets. As each amount is set up in the machine the proper classification key is depressed. The water consumed is classified into rate groups as it is set up. Each postal card and bill carries the account number of the ledger sheet from which it was copied.

As bills and cards are completed they are placed in the rack according to list classifications. Should the ledger show that there is a bill to be made for an account that was vacant the previous month, the clerk substitutes a postal card for the plain card which she has for every vacant account and notes on the plain card the account is now occupied.

Should the reverse be true, that is a previously occupied account being vacant the clerk will note on the postal card that the account is vacant. At the end of the day these corrections are made on the Addressograph plate.

All accumulators of the analysis machine are cleared at the end of each five hundred. The amount shown by the total billing accumulator is checked against the ledger control as is the total amount of water consumed.

The audit sheet which is a copy of all bills made, is then turned over to the department's accountant who checks the total billing and total water consumed against the summary sheet totals for the ledger. In addition, he audits the billing by using the rate analysis of the water consumed.

Credits are posted each day. The office copy of the bills collected, together with tape is sent to the bookkeeping office by the collection office each day. The bills are checked against the tape and then put in numerical order for posting.

The summary sheet provided for the credit posting is the same as the one used for debit.

The first operation in posting credits is to post the amount paid, then amount rebated, if any, and sundries. The machine automatically tabulates to the old balance position, which is picked up and the machine cleared in the new balance column.

Totals are taken for every five hundred accounts, the accumulated totals being amount paid and the amount of rebates. These are posted to the individual ledger controlling accounts and main controlling account. Should there be any sundries in the group an adding machine tape is made of these and posted to the control. The number two accumulator on the machine being left open for any credit balances that may appear on the ledger.

The total postings of all individual ledgers must equal the amount reported collected by the collection office.

At the end of the month an adding machine tape similar to the summary sheet is made of all new balances for each ledger of five hundred accounts and checked against the controlling account.

After proving the ledger, the ledger sheets are taken to the analysis machine where arrears are put on the postal card and bill. The account number and the amount of the new bill is picked up on the audit sheet, and bill and card inserted in the machine, the amount of arrears set in the machine and total taken. In this way we are

enabled to prove that the amount of arrears put on bills and postal cards equal the amount as shown by the ledger.

We believe that this new installation will be flexible and that it will meet any conditions that will arise in future years. We know that we are equipped to go immediately into a deposit system should it be required, and that we can go on a continuous billing and mailing basis within twenty-four hours notice.

## CONTROL SYSTEM

Our next step is to establish an adequate control system in the collection office that will provide the necessary information that will insure the proper handling of the money.

This control will be based on the recording of each individual item handled by each cashier on a cash register in such a manner as to enforce the responsibility of the correct handling of the item.

It will provide nine important features.

(1) The segregation of receipts in accordance with source of revenue; (2) the segregation of rebates allowed; (3) the segregation of transactions by cash and check and those where money is paid to customers whose checks are in excess of the bill paid; (4) the listing of bills where more than one is paid by a customer; (5) a secret total which will be accessible only to the Commissioner of Finance or his authorized agent; (6) the certification in one operation on the receipt, the office copy and check where paid by check; the account number; the source of revenue and the type of transaction, cashier and amount paid; (7) separate cash drawers with different tone bells for each cashier; (8) a lock for each cashier's control key and (9), a daily audit sheet of all transactions.

It will not provide for cash refunds by the cashier.

With the foregoing provisions it will be necessary for the cashier to set up the amount keys, the revenue classification and transaction control keys, the account number and the proper cashier's key before the machine will operate.

The receipt and office copy of each bill paid will be certified as to date, transaction number, account number, revenue classification, type of transaction, the amount paid and the cashier collecting same. Should the bill be paid by check it will be inserted in a check certifying device at the same time the bill is inserted in the billing certifying device.

The check certification will bear the same data as the receipt and office copy.

With this provision the bank can refuse to accept checks not bearing proper centification.

In the event that a check is returned for insufficient funds the exact amount can be charged back to the proper account.

On accounts where rebates are allowed the amount rebated and the amount paid will be certified on the receipt and office copies.

At the end of the day, the cashier's totals will be read and cash balanced. The readings will be printed on the daily audit sheet and will show the number of transactions of each cashier and the amount collected.

After the cash is balanced all totals are cleared and the accumulated amounts printed on the daily audit sheet and a daily take off form a copy of which will go to the Commissioner of Finance's office for his files.

The work of the cashier in balancing will be facilitated, since it will not be necessary to make an adding machine tape of his collections or to classify them. All of this information will be shown on the detail audit sheet. The detailed audit sheet will go to the bookkeeping office daily together with the office copy of bills collected. Should a bill be missing it will be detected in the bookkeeping office check, a note made and credit will be posted to the account from the detailed audit sheet.

With our new system and the above proposed installation in the collection office we will have a very definite control over billing, meter readings and collections.

*(Presented before the North Carolina Section Meeting, November 1, 1932.)*

# PUMPING STATION AND FILTRATION PLANT AT ST. JOSEPH, MICHIGAN

By F. G. Gordon

(*Consulting Engineer, Chicago, Ill.*)

The 4,000,000-gallon filtration plant and pumping station completed for the City of St. Joseph, Michigan, replaces an old steam plant which took its supply from the lake and delivered it into the distribution system without any other treatment than chlorination. This old plant, in addition to boilers and steam pump, included a producer gas plant and a gas engine and generator to provide power for the street lighting system, which is owned by the City.

At the time the City decided to construct a filtration plant, studies were made to determine the best source of power for the pumping station and street lighting load. A rate of 1.5 cents per kilowatt hour was offered by the local power company and, after consideration of steam, diesel and purchased power, the City selected purchased power.

The maximum daily pumpage at St. Joseph occurs during the summer months and has been about 2.6 million gallons. The City approved the construction of a filter plant having a capacity of 4,000,000 gallons, with 1,000,000 gallons of clear water storage capacity. Plans were prepared for such a plant, to be located near the site of the existing plant, and the general contract for the work was let in May, 1931.

The principal structures of the new plant include a suction well, a low lift pump pit, mixing tanks, sedimentation basins, filters, clear wells below the filters, a reservoir, pump room, chemical room, office and laboratory, toilet rooms, transformer and switch room, furnace room and shop.

## SUCTION WELL AND INTAKE CONNECTIONS

The suction well is a circular concrete shaft, 10 feet inside diameter, and with its bottom at a point approximately 25 feet below average lake level.

A 20-inch cast iron pipe connects this suction well with the existing

intake line, and this 20-inch pipe turns down into the well to a point slightly above the bottom. With this arrangement a siphon action is started in the intake line whenever the water in the suction well is drawn down below the level of the water in the lake and the quantity of water which the intake will deliver is materially increased.

A screen on the center line of the well keeps fish, leaves, etc. from entering the pump suction.

### LOW LIFT PUMP PIT

The low lift pump pit is a circular shaft 20 feet in inside diameter and located at the southwest corner of the pump room, immediately adjacent to the suction well. The bottom of the low lift pump pit

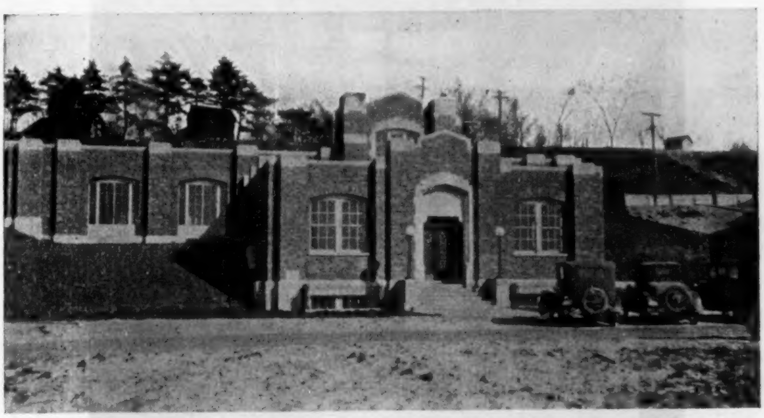


FIG. 1. EXTERIOR OF FILTRATION PLANT

is about 6.5 feet below average lake level, and 20 feet below the floor of the pump room itself. The low lift pumps have capacities of 1, 2 and 3 m.g.d. respectively, and are motor-driven centrifugal units. These pumps discharge into a cast iron line leading to the mixing chamber.

### MIXING TANKS AND SEDIMENTATION BASINS

The two mixing tanks and sedimentation basins form two duplicate units, so arranged that water may be passed through each set, either in parallel or in series. The mixing tanks are octagonal tanks, each equipped with a stirring device consisting of a central shaft, two arms and plates suspended from the arms. This shaft is driven through a

speed reducer by a variable speed motor. The water flows over a weir from the mixing chamber into the adjoining sedimentation basin, each unit of which has a longitudinal baffle wall extending nearly to the end of the tank. The travel of the water in each sedimentation basin is to the end of the tank and back again on the other side of the

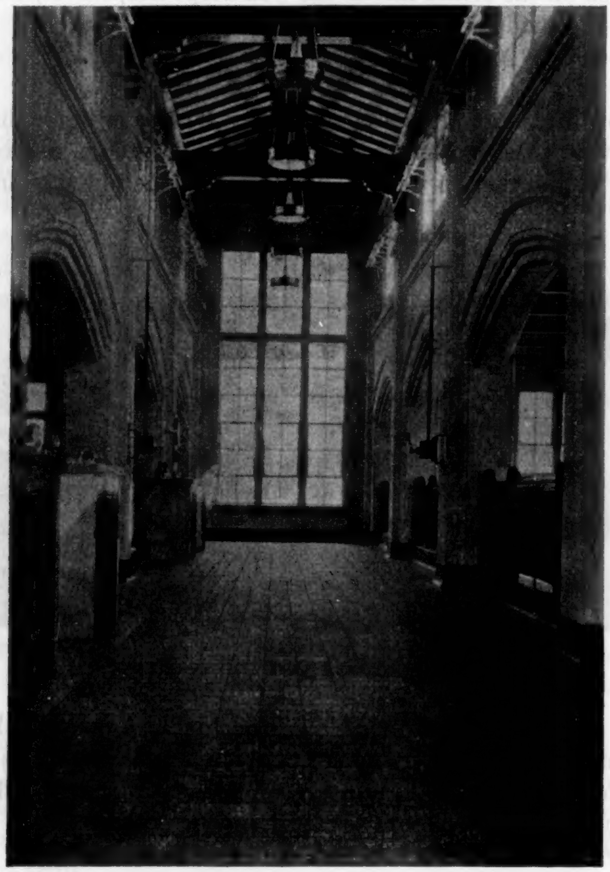


Fig. 2. Filter Operating Floor

baffle wall. The far end of each sedimentation basin unit is semicircular in plan in order to promote a smooth flow of water around the end and thus avoid dead spots.

The detention period in the mixing tanks is 15 minutes, and in the sedimentation basins is 3 hours when the plant is operating at rated capacity.

### FILTERS

Each of the four filters is 352 square feet in area, and is provided with 3-inch cast iron pipe laterals in the under drain system. Each filter is equipped with hydraulically operated valves, rate of flow controllers and loss of head and rate of flow gauges. A departure from the usual design consists of the placing of the influent and drain piping at the back of the filter and the effluent and wash water connections at the front. Water for washing the filters is furnished by a wash water pump. Push button control of this pump is provided at the operating tables. An indicator controlled by an orifice meter on the wash water line enables the operator to note the rate of wash. The filters are designed for washing at a rate corresponding to a 24 inch vertical rise per minute.

### FILTERED WATER STORAGE

Immediately below the filters is a filtered water storage space which is divided into two parts by a division wall. In addition to this storage space, a reinforced concrete covered reservoir is located immediately in front of the plant. This reservoir is 108 feet long, 92 feet wide and 12 feet 4 inches deep in inside dimensions. It has a flat slab roof, supported by 30 circular columns 16 inches in diameter. The reservoir, together with the storage under the filters, provides a total filtered water storage capacity of 1,000,000 gallons. Water from the filters under ordinary operation flows to the clear water reservoir and must flow through this reservoir before passing to the clear wells below the filters themselves. With this arrangement chlorine is introduced into the line extending to the reservoir. Piping connections are so arranged that is is possible to short circuit the reservoir and allow water from the filters to flow directly to the clear wells immediately below them.

### HIGH SERVICE PUMP ROOM

The high service pump room houses two motor-driven centrifugal pumps for domestic service, two motor-driven centrifugal fire pumps, and one wash water pump. One of the fire pumps is a dual unit with gasoline engine, as well as motor drive. The suction for these pumps consists of a loop header, one end of the loop being connected to one of the clear wells under the filters and the other end of the suction header into the other clear well. This suction header is so valved that water may be drawn from either of these clear wells. A discharge

header from the pumps extends through the wall of the building and thence to its connection with the existing transmission line to the distribution system. A venturi tube used in metering the water pumped is located in a meter vault outside the building.

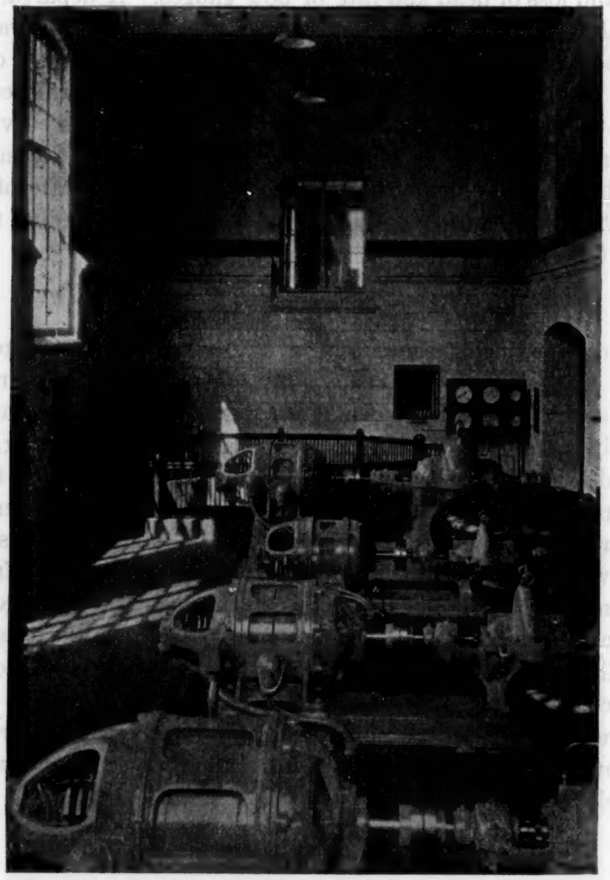


FIG. 3. INTERIOR OF PUMPING STATION

### TRANSFORMER AND SWITCH ROOM

A room adjacent to the pump room houses two transformers, switching equipment, and the street lighting regulators for the various street lighting circuits. Power is furnished to the plant through two independent 4000 volt lines. The transformers and switching equipment are in duplicate and are so arranged that in the event of

interruption of power on one of the circuits leading to the plant, it is possible to throw over immediately to the other circuit.

### MISCELLANEOUS UNITS

The office and laboratory is located at the end of the pump room, and a window in the wall between these two rooms makes it possible for the Engineer to watch the pump room at all times.

On the opposite side of the central hallway leading from the front door to the pump and filter room are located the chlorine room and two toilet rooms. The chlorine room is provided with a motor-driven exhaust fan to force all chlorine fumes out of the room in case of any leakage of gas from the chlorine equipment.

The furnace room and shop is directly below the office section of the building. Fuel oil is used for fuel in the heating boiler and a hot water tank is provided with connections to the boiler and with an electrical heating unit for service when the boiler is not in operation.

The heating system is a combination of radiators and unit heaters. The office, laboratory and toilet rooms are heated with radiators; the pump room is heated by two unit heaters; the chemical room is heated with one unit heater; while additional heat on the control gallery floor is secured from radiators mounted on the under side of the floor, the heat from which passes through the control tables. Copper piping has been used for the steam and return lines from the radiators and unit heaters.

The building is constructed of brick with stone trim. All windows are fitted with steel sash. The roof consists of concrete slabs laid on steel rafters, with cork insulation placed over the concrete roof slabs. The walls of the filter room, control gallery and pump room above the control gallery floor level are finished in ornamental stone plaster. The walls of the pump room below the control gallery floor level are terra cotta. The floors of the entrance hallway, control gallery and pump room are of red quarry tile, with terrazzo border and curb. With the exception of the wood hand rails and wood trim in the office section, the building is completely fire-proof throughout.

The personnel connected with the design and construction of the plant were V. A. Matteson, Architect; Gordon & Bulot, Engineers; H. G. Crow, City Manager; John Erickson and D. E. Bicknell, representing the City on Supervision of Construction; and the Lovering-Longbotham Company, General Contractors.

*(Presented before the Illinois Section meeting, April 12, 1932.)*

# WATER SOFTENING AT BOULDER CITY

By Earl M. Kelly

*(Engineer, The Dorr Company, Inc., Los Angeles, California)*

Boulder City, Nevada, the construction city of the Hoover Dam project and the center of so many remarkable engineering achievements, has the further distinction of being the first community to soften Colorado River water for domestic consumption.

Realizing the expediency of furnishing the prospective inhabitants of this desert community with a water of highest quality, the United States Bureau of Reclamation included an unusually modern water treatment plant in their plans.

A study of the characteristics of the Colorado River, which surveys showed to be the most logical raw water source, revealed the fact it is not only extremely turbid, but very hard. Analyses made by the United States Geological Survey at Grand Canyon, for the years 1926–1928 indicated a suspended solids content ranging from 350 to 59,400, with an approximate average of 6000 p.p.m. The average mineral content of the water for this period was as follows:

| | |
|---|---|
| Silica ($SiO_2$) | 16 |
| Iron (Fe) | 0.22 |
| Calcium (Ca) | 93 |
| Magnesium (Mg) | 33 |
| Sodium (Na) | 118 |
| Potassium (K) | 6.4 |
| Bicarbonate radicle ($HCO_3$) | 192 |
| Sulfate radicle ($SO_4$) | 328 |
| Chloride radicle (Cl) | 93 |
| Nitrate radicle ($NO_3$) | 4.7 |
| Hardness as $CaCO_3$: | |
| Non-carbonate | 209 |
| Carbonate | 158 |
| Total | 367 |

The data showed the water to be very flashy, the total hardness varying from 144 minimum to 636 p.p.m. maximum. The minimum hardness occurs in the Spring, during flood periods when the river is

swelled by melting snow and rain waters. Maximum hardness occurs late in the year when the river discharge is low.

Having a water of such high average hardness and varying characteristics to treat, it was deemed not only advisable to provide complete softening, but to design the plant for maximum flexibility. As a result the Boulder City waterworks is recognized as one of the most modern water softening plants in the country. Its design and process have proven entirely capable of easily handling this very difficult water successfully, and it reflects much credit on the United States Bureau of Reclamation, designers and builders of the plant, and Mr. Burton Lowther, the consulting engineer on the project.

### DESCRIPTION OF PLANT

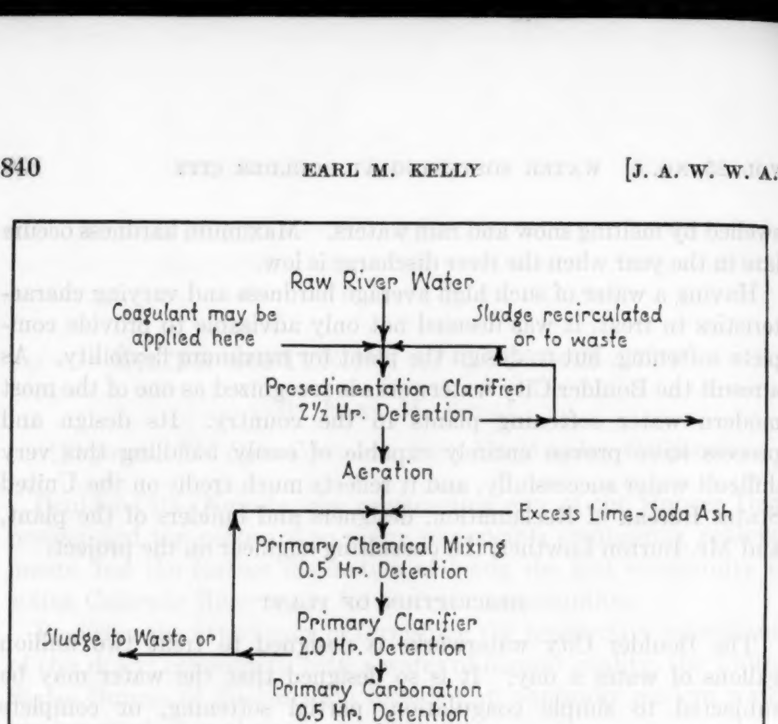
The Boulder City waterworks is designed to treat two million gallons of water a day. It is so designed that the water may be subjected to simple coagulation, partial softening, or complete softening, depending on the characteristics of the water. The units, with the exception of the presedimentation clarifier, are arranged to permit either series or parallel operation. Since the plant commenced operating various conditions have been encountered, and it has been found that the most satisfactory all around treatment is given by plain subsidence, followed by excess lime-soda ash softening, with series flocculation, sedimentation, and carbonation. An illustration of the flow sheet of this process is given in figure 1.

The treatment process used at this plant is relatively new, and is not practiced in any other far western plant. For this reason it is felt a brief résumé of the steps involved will be of interest.

Raw water is pumped from the Colorado River to a 55 feet square by 11 feet side water depth Dorr Traction Clarifier, situated on a bank of the river. This clarifier allows a plain subsidence period of two and one-half hours, which is sufficient to remove an average of over 95 percent of the suspended solids from the water. Presedimentation is absolutely essential because of the great amount of suspended material in this water.

To minimize water losses, sludge is withdrawn from the bottom of the clarifier uniformly, in a thickened condition, by a Dorrco Duplex Sludge Pump. Byron-Jackson pumps transport the settled water from the presedimentation clarifier to the softening plant in Boulder City, a distance of about 7 miles, against a static head of 1836 feet.

The first step in the process is aeration. Following this the water



Flow Sheet of Boulder City Water Treatment System at Rate of 2.0 Million Gallons per Day

Fig. 1

is dosed with lime and soda ash, and is mixed and flocculated in the two 14 feet square primary Dorr Impeller Agitators. The detention and mixing velocities of these units have been admirably chosen, and the floc formation is unusually good.

The chemical addition is regulated so that just enough soda ash is added to combine with the non-carbonate hardness. Excess lime over that required, sufficient in quantity to produce a causticity of about 40 p.p.m. at the end of the sedimentation period is found to give the best results. This excess treatment effects a high removal of the magnesium, and produces a heavy floc capable of coagulating and removing the suspended silt not dropped at the river.

Primary flocculation is followed by a sedimentation period of two hours in the primary clarifier, which is equipped with a 45 feet square Dorr Traction Clarifier.

The settled water is given partial carbonation for a period of thirty minutes, and sufficient $CO_2$ gas is added to convert the causticity (which is in the form of calcium hydroxide) to calcium carbonate.

The carbonates formed, although suspended, are so fine they settle too slowly to be completely removed by sedimentation. To remedy this the water is dosed with alum, or recirculated sludge, flocculated in secondary Dorr Agitators, and allowed to settle in the secondary Dorr Clarifier. The effluent is given further carbonation to convert any existing carbonates to soluble bicarbonates. It is then filtered, chlorinated, and pumped into the distribution reservoir.

The secondary agitator, clarifier and carbonation basins are identical with the primary units.

The sludge from the clarifiers, removed by Dorrco Sludge Pumps, may either be wasted, or recirculated.

To illustrate chemical changes occurring at the various steps of the process, the results of the treatment on March 2, 1932 are given in table 1.

The total hardness of the water applied to the filters was only 80 p.p.m. of which 70 p.p.m. was in the form of carbonates and bicarbonates. As the carbonates existed as fine suspended particles it is safe to assume that most of the 40 p.p.m. were removed by the filters, and a water having a total hardness of much less than 80 p.p.m. was delivered to the consumer. No coagulant or return sludge was added and the removal of carbonates in the secondary clarifier was not as great as desirable.

Major Forrester, sanitary engineer in charge of the plant, has recently worked out a modification of the above process which acts extremely well on this water, and has made possible a higher percentage removal of carbonate hardness. With this system it is found that best results are obtained by the recirculation of sludge from the primary clarifier to the primary agitators, and by maintain-

ing a hydroxide content of 52 p.p.m. in the primary clarifier overflow. The tests made on October 11, 1932 and shown in table 2 aptly illustrate the changes occurring at the various steps in the treatment.

It will be noted a removal of 74.2 percent of the carbonate hardness was effected, compared to a removal of 61.2 percent, as shown by the results of March 2, 1932, using the original process. The higher

TABLE 1

*Results of treatment in p.p.m. calcium carbonate*

| | RAW WATER | EFFLUENT PRIMARY CLARIFIER | EFFLUENT PRIMARY CARBONATION | EFFLUENT SECOND CLARIFIER | EFFLUENT SECOND CARBONATION |
|---|---|---|---|---|---|
| Total hardness | 470 | 105 | 92 | 88 | 80 |
| Methyl orange alkalinity | 180 | 98 | 86 | 75 | 70 |
| Phenolphthalein alkalinity | 0 | 69 | 45 | 36 | 20 |
| Free $CO_2$ | 12 | 0 | 0 | 0 | 0 |
| Carbonates | 0 | 58 | 82 | 72 | 40 |
| Bicarbonates | 180 | 0 | 0 | 3 | 30 |
| Hydroxides | 0 | 40 | 4 | 0 | 0 |

TABLE 2

*Results of modified treatment in p.p.m. calcium carbonate*

| | RAW WATER | EFFLUENT PRIMARY CLARIFIER | EFFLUENT PRIMARY CARBONATION | EFFLUENT SECOND CLARIFIER | EFFLUENT SECOND CARBONATION |
|---|---|---|---|---|---|
| Total hardness | 500 | 130 | 115 | 103 | 113 |
| Methyl orange alkalinity | 170 | 84 | 44 | 36 | 44 |
| Phenolphthalein alkalinity | 0 | 68 | 24 | 19 | 0 |
| Free $CO_2$ | 0 | 0 | 0 | 0 | 12 |
| Carbonates | 0 | 32 | 40 | 34 | 0 |
| Bicarbonates | 170 | 0 | 0 | 0 | 44 |
| Hydroxides | 0 | 52 | 4 | 2 | 0 |

removal was undoubtedly due to superior flocculation, caused by a combination of return sludge and larger floc formation due to carbonation of the higher hydroxide content.

## OPERATION

The complete Boulder City water treatment system was placed in operation the latter part of February, 1932. The consumption then

was but 0.3 m.g.d. This figure has been increased steadily, as the result of the growth of the city, and a natural higher water demand during the Summer months.

It has been the practice to operate the plant intermittently; usually twelve hours a day. Under this scheme of operation the quantity of water required during the period of twelve hours can be delivered by using one, two, or three pumps at each pumping plant. Thus, although the total quantity of water treated per day is small, the flow through the plant is at the rate of approximately 0.67, 1.33, or 2.0 m.g.d., depending on the number of pumps used.

During the first five months of operation 96.6 percent of the total suspended solids in the raw water were removed by the presedimentation clarifier. This amounted to an average of 37,400 pounds dry solids per day, or at the rate of 81,750 pounds per million gallons. The clarifier mechanism has handled these solids easily, and has required practically no attention other than an occasional lubrication.

TABLE 3

*Removals of suspended solids by presedimentation clarifier*

| MONTH | AVERAGE QUANTITY PUMPED (GALLONS PER DAY) | SUSPENDED SOLIDS (P.P.M.) | | | | | | PER CENT REMOVAL AVERAGE |
|---|---|---|---|---|---|---|---|---|
| | | Influent | | | Effluent | | | |
| | | Maximum | Minimum | Average | Maximum | Minimum | Average | |
| March | 317,000 | 22,000 | 6,400 | 11,820 | 2,050 | 100 | 303 | 97.4 |
| April | 340,000 | 29,850 | 8,560 | 13,120 | 320 | 25 | 130 | 99.0 |
| May | 374,300 | 14,800 | 3,670 | 8,350 | 425 | 45 | 230 | 97.3 |
| June | 587,400 | 17,100 | 4,052 | 8,807 | 595 | 109 | 246 | 97.2 |
| July | 668,750 | 27,540 | 1,270 | 8,460 | 13,100 | 11 | 677 | 92.0 |

Table 3 furnishes operating data on the presedimentation clarifier for the five months mentioned above.

The low removal for July was caused by an abnormal condition of one day duration, on July 18. On that day the suspended matter was of colloidal nature and it was possible to reduce it from 27,540 to only 13,100 p.p.m. by plain subsidence. The remainder, however, was readily coagulated at the softening plant.

That the type of treatment and flow sheet adopted at Boulder City is admirably suited for the treatment of Colorado River water has been fully demonstrated during the first months of operation of the softening plant.

During the first five months of operation the total hardness varied from 553 to 100 p.p.m. Changes occur quickly and variations of over 200 p.p.m. total hardness within a period of three hours have occurred. The percent carbonate and non-carbonate hardnesses in the raw water is also subject to frequent and wide variations. Notwithstanding such variable conditions, the softening plant has been able to deliver a clear, sparkling water having an average total hardness of less than 90 p.p.m. As it is desired to deliver a water having a total hardness of approximately 100 p.p.m. no attempt has been made to determine the lowest hardness limits attainable at this plant. However, in ordinary operation waters having a total hardness as

TABLE 4

*Characteristics of influent to softened plant*

| MONTH | HARDNESS IN P.P.M. $CaCO_3$ | | | | | | | | | FREE $CO_2$ (P.P.M.)* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Total | | | Non-carbonate | | | Carbonate | | | | | |
| | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average |
| March | 553 | 357 | 433 | 369 | 199 | 266 | 190 | 158 | 174 | 12.0 | 1.0 | 5.1 |
| April | 365 | 189 | 258 | 193 | 59 | 115 | 172 | 120 | 143 | 12.0 | 0.0 | 2.8 |
| May | 233 | 102 | 156 | 115 | 0 | 45 | 136 | 88 | 111 | 5.0 | 1.0 | 3.6 |
| June | 140 | 100 | 113 | 50 | 0 | 21 | 106 | 66 | 92 | 5.0 | 0.0 | 2.6 |
| July | 524 | 124 | 238 | 431 | 27 | 134 | 126 | 88 | 104 | 2.0 | 0.0 | 0.25 |

* After passing through Aero-Mix Aerator. Negative non-carbonate hardness occurred twice in May, and once in June.

low as 53 and 32 p.p.m. methyl orange alkalinities, have been produced.

Tables 4 and 5 give data on the hardness of the raw and the treated waters for the monthly periods considered.

The monthly chemical requirements vary widely over a yearly period. Table 6 gives the amount used, and the chemical cost of each, per million gallons treated. From this it will be seen that the average chemical cost per million gallons for the first five months was \$28.17, or only 2.82 cents per thousand gallons of water.

The above treatment produces a water of excellent filtering qualities, with filter runs averaging from 45 to 50 hours.

Although the excess lime-soda ash treatment is undoubtedly very efficient in sterilizing the water, for absolute safety a small chlorine

addition is required for a residual of from 0.1 to 0.2 p.p.m. after twenty minutes' contact, is made.

Recently a condition occurred at Boulder City which presented one of the most difficult treatment problems ever experienced in a municipal water treatment plant. In the last three days of August the characteristics of the suspended matter in the Colorado River under-

TABLE 5

*Characteristics of treated water*

| MONTH | HARDNESS IN P.P.M. $CaCO_3$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Total | | | Non-carbonate | | | Carbonate | | |
| | Maximum | Minimum | Average | Maximum | Minimum | Average | Maximum | Minimum | Average |
| March* | 170 | 80 | 95 | 84 | 0 | 11 | 123 | 64 | 84 |
| April* | 108 | 53 | 84 | 58 | 0 | 4 | 108 | 48 | 80 |
| May* | 106 | 60 | 88 | 69 | 0 | 42 | 78 | 32 | 46 |
| June | 94 | 53 | 72 | 52 | 9 | 29 | 56 | 32 | 43 |
| July | 150 | 71 | 103 | 105 | 4 | 43 | 96 | 32 | 60 |

* Sodium alkalinity exceeded total hardness three times in March; ten times in April; twice in May.

TABLE 6

*Chemical requirements*

| MONTH | AVERAGE CHEMICALS USED (POUNDS PER M.G.) | | | | CHEMICAL COST PER M.G. (DOLLARS)* | | | | TOTAL CHEMICAL COST (DOLLARS PER M.G.) |
|---|---|---|---|---|---|---|---|---|---|
| | Lime | Soda ash | Alum | Coke | Lime | Soda ash | Alum | Coke | |
| March | 2,080 | 2,025 | 0 | 485 | 15.81 | 30.02 | 0 | 2.98 | 48.81 |
| April | 1,694 | 1,256 | 0 | 574 | 12.87 | 18.62 | 0 | 3.52 | 35.01 |
| May | 1,365 | 143 | 188 | 494 | 10.37 | 2.12 | 4.48 | 3.03 | 20.00 |
| June | 1,088 | 0 | 65 | 329 | 8.27 | 0 | 1.55 | 2.02 | 11.84 |
| July | 1,234 | 897 | 20 | 330 | 9.38 | 12.30 | 0.48 | 2.02 | 25.18 |

* Lime at $15.20 per ton; soda ash at $29.65 per ton; alum at $47.70 per ton; coke at $12.26 per ton.

Chemical costs based on typical contract prices plus domestic freight rates.

went a marked changed. The material became much finer than usual, and the amount carried by the river greater. Very little of the solids were removable by plain subsidence, even at detention periods as long as seven and one-half hours. Lime, soda ash, alum, and other chemicals were tried in an attempt to coagulate the solids, but it was impossible to flocculate the material. Consequently, very

little was removed in the clarifiers at the softening plant, and most of it went to the filters. Filter operation was reduced to half hour runs and considerable of the material even passed through the filters. More water was required to wash the filters than passed through them. Analysis made on September 1 showed the raw water contained 84,444 p.p.m. suspended solids, and it had a total hardness of 798 p.p.m. During the period of bad water and total hardness went as high as 904 p.p.m.

On September 4, following a series of experiments made by Major Forrester and the writer, the plant was placed in operation using a different process, which satisfactorily handled the bad water.

The influent to the presedimentation clarifier, on September 5, contained 70,529 p.p.m. suspended solids. This was dosed with lime and a removal of 38,570 p.p.m. was accomplished at this point.

The softening plant influent containing 31,595 p.p.m. suspended solids, was dosed with sufficient lime to produce a hydroxide content of over 250 p.p.m. in the effluent from the primary clarifier. Floc formation in the primary clarifier was practically negligible, and the overflow contained approximately 19,000 p.p.m.

This effluent was given a heavy $CO_2$ treatment in the primary carbonation basin, with a resultant heavy floc formation of 5.5 feet per hour settling rate. The heavy calcium carbonate floc was extremely efficient in sweeping down the colloidal material and gave a clear overflow. A slight dose of alum was given the flocculated water just ahead of the secondary mixers, to expedite the removal of the very fine material.

As a result of this unusual procedure the heavy material settled out completely in the secondary clarifier, and the overflow from this unit was as clear as usual and could be satisfactorily handled on the filters without undue head loss or filter washing.

ACKNOWLEDGMENT

The Boulder City Water Works System was designed and constructed by the United States Bureau of Reclamation. Mr. Burton Lowther was Consulting Engineer on the project. The operating data contained in this article were made possible through the kind coöperation of Mr. Walker Young, Construction Engineer at Hoover Dam, Major D. M. Forrester, Sanitary Engineer for the bureau at Boulder City, and other United States Bureau of Reclamation engineers.

*(Presented before the California Section meeting, October 27, 1932.)*

# BEAUTIFICATION OF WATER WORKS PROPERTIES

By Wm. W. Hurlbut

*(Engineer of Water Works, Bureau of Water Works and Supply, Department of Water and Power, Los Angeles, Calif.)*

Problems connected with the beautification of water works properties are many, due to the various types of structures involved. During the past two decades there has been an increased interest shown by the public in good water supply,—good both as to quantity and quality. In all probability this interest may be attributed to the expenditure of large sums of money and the resultant creation of fine structures and exemplary works for supplying, purifying and distributing waters. Water works properties and structures constitute some of the major public works of this country. A very large percentage of the enormous investment in water works systems is not visible, but is buried in the form of substructures and the extensive distribution pipe systems. However, it is this phase of the water works that records the pulse of the consumer, who is generally interested only in sparkling, clear water, served under good pressure. The results of water works construction as obtained during the last generation have been to provide an adequate supply of water with the proper pressure to serve all of the needs of the community, and in this stage of the development also not only to build structures that are architecturally beautiful but to beautify the properties contiguous to reservoirs, pumping plants and similar structures.

The City of Los Angeles has invested in its water works approximately \$120,000,000, being one of the largest water works plants in America. Up to approximately five years ago the engineers who had in charge the planning, building and operating of these works were stressed to the utmost in taking care of the needs of the growth of the community. They could spare but little capital to be applied to the physical beautification of the properties. However, since that time there has been a well developed program for the beautification of all properties lying within the city.

Having been a member of the engineering staff of the Bureau of Water Works and Supply of the City of Los Angeles for the past twenty-five years and being intimate with the system and the demands made upon it, I will endeavor to illustrate the problems of the beautification of its properties and the results obtained.

The physical condition of the visible portions of the water works in every community is naturally influenced by the climatology, and as an illustration of this fact I will endeavor to show what this asset means to the Los Angeles Water Works. We certainly have taken advantage of Nature's contribution by utilizing plant life to permanently beautify our works.

In Southern California, endowed with a semi-tropical climate, areas which were seemingly a barren waste have been transformed in a short period of time into pleasing vistas.

Our growing season is continuous throughout the year and we resort to the use of seasonal flora and of trees, shrubs and vines that are evergreen.

## TANKS

One of the most difficult problems with which to cope was that of the steel tank. Steel tanks are usually unsightly. However, this condition can be overcome by the use of masonry or concrete in changing the type of the structure, providing that the expense would be warranted, that is, if the location in which the tank is constructed is in a highly developed district.

There are fifty-one tanks and small reservoirs in the Los Angeles system. Most of these tanks were built ahead of the development of the area in which they are located. There is one tank in particular, called the Finley Avenue Tank, in the East Hollywood District, erected in 1922, being 47 feet high and 80 feet in diameter, which caused the Department of Water and Power a great deal of concern due to the numerous protests received as to the location of this tank, charges being made that the tank destroyed the value of the property for residential purposes, and its abandonment was demanded. Due to elevation, topography and the requirements of the distribution system, it was necessary to construct a steel tank rather than an underground reservoir, the adornment of which is simple compared to the treatment necessary to make a steel tank non-objectionable in a residential area. Four years ago the grounds surrounding this tank were properly landscaped and beautified with lawns and shrubs

and the Tecoma australis, or Wonga-wonga vine of Australia, was planted throughout the perimeter of the tank. Today this vine has totally obscured the tank and made the premises a thing of beauty rather than one of detriment. To quote from Miss Alice Koons in the Los Angeles Times of September 18, 1932:

> It looks like the ivied wall of some storied Spanish castle, but it's only a city water tank clothed with vines and flanked with palms and other trees. Because someone had the taste and cleverness to do the work, people in fine homes all around don't mind at all living right next the "waterworks."

Other tanks of this type have been camouflaged by the planting of gum, cypress and other trees and today are totally obscured.

### PUMPING PLANTS

There are thirty-four pumping plants and ten chlorinating plants in the Los Angeles system, and all of the modern plants built within the past decade have been so located on the site as to lend themselves to proper landscaping in the form of planting lawns, flowers and shrubs. This type of structure has no unusual problems to solve from the standpoint of beautification, and as a matter of fact most of these plants are located in residential districts and have the appearance of a small branch library rather than a pumping plant.

The plans of all buildings erected by the Department under a provision of the City Charter must have the approval of the Art Commission and consequently the types are architecturally in harmony with the improvements in the locality in which they are built.

### RESERVOIRS

To one plant in particular I wish to call your attention; in fact it is the largest plant in the system,—the North Hollywood Plant located in the San Fernando Valley in a residential district. The portion of the premises that was the most difficult to beautify was the 3,000,000-gallon dug reservoir in the rear of the plant. Soil conditions in this area are river wash sand and it was found that in order to sustain any growth on the slope it would be necessary to pave the slopes, so the material selected for paving was cobble stones from the Tujunga Wash, and an interplanting of Mesembryanthemum on these slopes gives the general appearance of a wide expanse of

verdure rather than barren banks. This plant is very generally used in covering the downstream slopes of many of the small dams.

In the beautification of the larger service reservoirs throughout the system it was found that where the dams were constructed of earth, the proper selection and planting of native shrubs and trees on the slopes gave the most pleasing effect, and this general scheme of beautification has been carried out on the Upper and Lower Franklin, Stone Canyon, Sawtelle Pressure Break and Silver Lake Dams. All of the above reservoir properties are now highly developed and properly enclosed with the highest type of fencing. The shore line of all of the large reservoirs throughout the system is treated and sprayed with oil as the water recedes, thereby controlling all weed growth, and at all times the banks have the appearance of a neat, clean and uniform slope.

Several of these reservoirs have concrete walls and highly developed roadways encircling them.

In the case of some of the smaller reservoirs that have been recently constructed in residential areas, the Department has resorted to the excavated, concrete lined reservoir, concrete covered, the cover being backfilled with three feet of earth and properly landscaped and planted, the effect being that of a small park.

In the building of a masonry or concrete dam the engineer has the best subject available for pleasing beautification, in the form of providing proper architectural embellishments in connection with the roadway capping the top of the dam. The only example of this type in the Los Angeles City system is that of the Mulholland Dam.

A well beautified reservoir is probably one of the best advertisements that the water works can have, as it emphasizes to the layman the conditions surrounding the premises which supply the water that we drink.

Notable progress in the beautification of water works properties has been obtained throughout California and is well established throughout the country.

There are works of great magnitude contemplated for the immediate future and undoubtedly they will embrace embellishments of beauty, whether they be structures or beautified landscapes.

*(Presented before the California Section meeting, October 27, 1932.)*

# CHLORINE TOLERANT BACTERIA IN WATER SUPPLIES

By David B. Charlton

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Apparently the first definite study of the minimal "Chlorine Death Points" of bacteria has been reported by Tonney, Greer and Danforth.[1] These authors have stated, "Although chlorine gas is universally used in the treatment of water supplies . . . . little, if any, work has been done to determine the least amount of chlorine required to kill known numbers of known species of bacteria under fixed conditions that admit of comparison of their relative resistance." The object of their work was to select an organism that could be used as a safe index of effective chlorine disinfection with special reference to pathogenic bacteria or those organisms considered to be of sanitary importance. They have found "*B. coli*," of which most strains were killed in chlorine concentration of 0.2 to 0.25 p.p.m. in 15 seconds, to be more resistant than the other vegetative forms studied.

## PRELIMINARY OBSERVATIONS

In the routine analyses of the local city water supply as well as of various other chlorinated water supplies in the state, the qualitative tests for the colon-aerogenes group are usually negative whereas varying and sometimes high bacterial plate counts are obtained. Members of the colon-aerogenes group were undoubtedly present in the raw water, but did not survive the chlorine dosage. It was apparent that certain species of bacteria were more resistant to chlorine than others. The same condition was observed in the water from the college swimming pools. In the daily analyses of the pool water it was possible to make accurate tests of the residual chlorine and note the concentrations necessary to keep the bacterial count at a minimum. During the past eighteen months (excluding certain intervals) experience has shown that when the residual chlorine concentration, as determined by the ortho-tolidin test was below 0.2 p.p.m., high bac-

[1] F. O. Tonney, F. E. Greer and T. F. Danforth: The Minimal "Chlorine Death Points" of Bacteria. Amer. Jour. Pub. Health, 18, part 2, 1259, 1928.

terial counts resulted, with occasional positive colon-aerogenes tests. When these positive tests have occurred, the residual chlorine was usually 0.1 p.p.m. or less. There seemed to be a residual chlorine concentration of 0.2 p.p.m. and sometimes above in which certain chlorine resistant bacteria could remain alive for considerable lengths of time.

A brief study was made of the commonly occurring resistant species, to see if their resistance to chlorine under experimental conditions were greater than that of certain other vegetative bacteria. A consideration of their bacteriological characteristics, their source, and possible significance in water, was included in the study.

## METHODS OF STUDY

Pure cultures were obtained by picking from the predominating colonies on the agar plates from chlorinated water samples. Most of the cultures were isolated from the swimming pool water in which the residual chlorine in the sample was 0.2 p.p.m. or above. All the residual chlorine determinations were made according to the standard ortho-tolidin test. Some of the isolations were made from the 24 hour 37°C. plates, and others from plates which had been held at room temperature, as some of the colonies would not develop at 37°C.

The methods used to test the resistance of these bacteria to chlorine were, stated briefly, as follows: Exposures were made in 300 cc. quantities of sterile distilled water to which approximately 0.05 cc. of a broth culture of the organism was added. Chlorine gas in water solution was added to produce the desired test concentration. Since it was desired to note the resistance of the bacteria to chlorine in brief exposures as well as through periods of an hour or more, dissipation of the chlorine was a factor, but with a little practice small amounts were added, so that the desired chlorine concentration could be maintained within a variation of 0.05 p.p.m.

## RESULTS AND DISCUSSION

Yellow pigmented colonies of possibly three types were observed most frequently, being very common in the pool water. Some of these would grow at 37°C., but slowly. Greenish fluorescent colonies which grew readily at 37°C. were very frequently present, sometimes in practically pure culture, from two chlorinated surface water supplies. Orange and pink colonies as well as some non-pigmented colonies were observed less frequently.

Only 30 pure cultures were isolated from hundreds of plates observed which showed the typical colonies because many were similar in cultural appearance. Of the 30 strains isolated, bacteriological study showed some of them to be identical or closely related species so that not all of these were used in the chlorine resistance experimental study.

As a preliminary check on the technique, tests were run on *Escherichia coli* which showed that in the presence of 0.1 p.p.m. of residual chlorine, the rate of destruction of bacteria was low, while at 0.2 p.p.m. disinfection was rapid. This agrees with the results of Tonney et al. For the practical objectives of this paper the detailed results need not be presented.

The isolated strains showed only slight individual differences in chlorine tolerance. The results will be considered as a group. A concentration of 0.2 p.p.m. was destructive, but the rate of disinfection was much slower than in the case of *Escherichia coli.* At this concentration the suspensions of the resistant species were not rendered sterile after exposures of 30 minutes or an hour. When a concentration of 0.4 p.p.m. was used, practically complete disinfection was obtained in a few minutes. This work was repeated a year later with similar results. The organisms were maintained on nutrient agar and transferred monthly.

This tolerance was not as great as was expected as most of the species were obtained from pool water in which the residual chlorine was often as high as 0.4 p.p.m. In trying to account for this a similar series of tests was made using sterilized swimming pool water in place of sterile distilled water as the suspension medium. Under these conditions considerably higher concentrations (0.5 p.p.m.) of residual chlorine were required to destroy the bacteria, showing that residual chlorine is more effective in distilled water than in the presence of small amounts of mineral and organic matter.

The chlorine resistant species studied were not identified, but certain morphological, cultural and physiological studies were made, which were sufficient to give a definite idea of their bacteriological relationships. All of the strains isolated were gram-negative short rods. This characteristic in regard to the pigmented bacteria places them in the tribe Chromobacteriae, of which the genera, Flavobacterium, Pseudomonas and Serratia were represented in the species studied. These bacteria constitute part of the natural water flora and hence are of little or no sanitary significance. Stock cultures of

*Serratia marcescens* and *Pseudomonas aeruginosa* were definitely more resistant to chlorine than *Escherichia coli* though slightly less resistant than the isolated species studied. The same was true of *Pseudomonas juglandis*, a plant pathogen. Other stock cultures of species from closely related genera, *Achromobacter viscosum* (a water type) *Proteus vulgaris* and *Alcaligenes fecalis* (intestinal type) were not appreciably if any more resistant than *Escherichia coli*.

The pigmented and fluorescent bacteria seem to possess a definitely greater chlorine tolerance than the intestinal rod forms and other closely related bacteria. They are not likely to be of any sanitary significance, although some species of Pseudomonas have been reported in certain infections. Certain strains, particularly those forming orange, pink and dark yellow colonies do not grow at 37°C. and are not counted in the routine standard plate count. The Pseudomonas strains studied grew quite well and formed visible colonies under the same conditions. These observations may be of assistance in interpreting excessively high counts with negative colon-aerogenes tests from swimming pool water. This preliminary study indicates that to have a relatively sterile pool water, the residual chlorine should be maintained at about 0.4 to 0.5 p.p.m. as determined by the ortho-tolidin test.

The writer wishes to acknowledge the help given to him in this study, by Helen Jarl and C. D. Adams.

# DOMINICK-LAUTER MEDIUM COMPARED WITH STANDARD LACTOSE BROTH FOR B. COLI TESTS

By H. V. Stewart, B.S.

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Bacteriologists, sanitarians, water plant operators, and all others connected with any phase of the drinking water problem are interested in any method of water examination or analysis that will produce dependable results in a shorter period of time.

The American Public Health Association through its committee on Standard Methods has adopted a scheme of examination of water samples that is usually referred to as the Standard Method (1), and the standard procedure for determining the presence of B. coli in water, is to use lactose broth prepared according to their recommendations as an enrichment medium followed by confirmation. This confirmation is time consuming and postpones for 24 to 96 hours the time in which a reliable report may be rendered.

The troublesome feature of the standard lactose broth has been that with certain water supplies, especially treated supplies, gas is produced in the presumptive tests by certain organisms or groups of organisms that are not members of the colon group. These may be spore bearing anaerobes or certain organisms that have the faculty of fermenting lactose when growing in symbiotic relationship with other organisms, but, since they are not necessarily of fecal origin they have little significance in water purification, and since gas formation is observed in these samples time must be consumed in determining whether the causative organism is a member of the colon group. Even after time has been spent in attempting this differentiation our results are not always conclusive as we frequently fail to find B. coli when present due to overgrowth by accompanying species.

Dominick-Lauter (2) have developed an enrichment medium for the examination of water samples that seems to offer hope that the time consumed in making an examination can be materially reduced. This medium has the same basic composition as the standard lactose broth, but with the addition of certain buffer salts and inhibitive dyes.

These inhibitive dyes used in the Dominick-Lauter medium retard the growth of the organisms that accompany the colon bacillus without appreciably affecting its development, thus allowing it to be isolated with a much greater degree of accuracy.

A study of the relationship between the Standard Lactose Broth and the Dominick-Lauter Medium was made by Leahy, Freeman and Katsamps, of the Rochester Health Bureau Laboratory (3), on 1116 samples of water from 358 different sources. Upon completion of their study they state that "The Dominick-Lauter Medium is far superior to the Standard Lactose Broth for the detection of B. coli in water." Their statement was based on the following conclusions.

1. The percent confirmation for the total number of tubes showing gas and the total number of samples showing gas was much higher in both cases for the new medium than for standard lactose broth.
2. The percent confirmation for the standard lactose broth tubes showing gas in 24 hours was higher than the percent confirmation for the standard lactose broth tubes showing gas in 48 hours, but the percent confirmation with the Dominick-Lauter tubes showing gas in 24 hours and 48 hours was approximately the same in each case.
3. The percent confirmation for the standard lactose broth increased as the amount of pollution in the water being tested increased, whereas the percent confirmation for the new medium remained approximately the same.
4. Of the total samples showing a positive presumptive test 100 per cent were confirmed for the new medium, whereas only 68.7 per cent were confirmed for standard lactose broth.

In Arkansas a similar study was undertaken and certain chemists, bacteriologists, and plant operators were asked to coöperate in the study by using this new medium in parallel with their usual technic, the idea being to observe the results from as many different types of water supplies as possible.

L. A. Jackson, Arkansas Water Company, Little Rock, Doctor Harrison Hale, University of Arkansas, Fayetteville, and the author, using the Dominick-Lauter medium in parallel with the standard lactose broth have obtained results that substantiate the conclusions reached by Leahy, Freeman and Katsamps.

Jackson of Little Rock sums up the results of his observations as follows:

"Up to the present time the test has run 220 consecutive days. Consequently 1100 tubes using Dominick-Lauter medium have been inoculated versus 1320 using lactose broth. The Dominick-Lauter medium has at no time shown

any trace of gas formation, while on the 1320 tubes of lactose broth, 16 show gas formation, 10 percent or over, at the end of the 48 hours. These however, proved to be only presumptive evidence of B. Coli, for in the confirmation test none of the 16 tubes were positive of the presence of B. coli. The above data seem to confirm the fact that the Dominick-Lauter medium does not show gas formation in the presence of any of the gas forming organisms, excepting B. coli. This however, was further substantiated by inoculating tubes of the new medium with samples of raw water known to contain B. coli. In each instance gas was formed in all of the inoculated tubes in large amounts in the 24 hour period. Also the color of the medium changed from its original deep purple color to one of red or reddish orange.

"Although the new medium showed a positive test in the case of polluted river water, we cannot definitely say what its reaction would be in the presence of a very slight pollution. However, the new medium has clearly demonstrated that it does not show gas for those gas forming organisms which do not confirm. Furthermore, it does confirm the presence of B. coli within 24 hours in a heavily polluted sample which is indicative at least that it is all it claims to be, a quick and positive medium to determine the presence of the B. coli group of organisms."

Hale of Fayetteville as a result of his observations on 29 samples using 156 tubes, states that

"The Dominick-Lauter medium has two advantages over the standard lactose broth, namely: that of speed and also the partial confirmation of B. coli by the use of organic stains. The gas formed during the first 24 hours is as large in the Dominick-Lauter medium in volume as that formed in 48 hours in the other medium. In other words, a positive presumptive test with standard lactose broth required twice as much time as with the Dominick-Lauter Media.

He also states that the use of the Dominick-Lauter medium in parallel with the standard lactose broth on routine tests of the Fayetteville city water supply over the past eight months yielded results comparable to those obtained by Jackson of Little Rock.

The author reports on 16 samples obtained from ten different sources. These supplies vary from those showing heavy pollution to those showing no pollution whatever and in no case did the standard medium show the presence of B. coli without this result being confirmed by the Dominick-Lauter medium, whereas the Dominick-Lauter test in one instance showed the presence of B. coli (confirmed on endo agar) while the standard medium though showing 50 per cent of gas failed to confirm on endo agar. In several other instances the standard medium showed a small amount of gas in one or more tubes which failed to confirm on endo agar while the Dominick-Lauter medium produced no gas whatsoever. These samples were from treated supplies that were expected to be free from B. coli pollution.

In view of the limited number of comparisons between the standard lactose broth and the Dominick-Lauter medium that have been made in this study it would not, at the present, be advisable to discontinue the use of standard lactose broth and substitute the Dominick-Lauter medium. In consequence of the excellent results obtained by this new procedure, however, it would be well to continue the study so that when more data are secured such a change might be desirable.

During the coming year the State Hygienic Laboratory will endeavor to obtain more data on those sources of supply that show only a small amount of pollution and thus show whether the Dominick-Lauter medium with its inhibiting dyes is sufficiently sensitive to be dependable in the so-called border line cases.

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# THE AMMONIA-CHLORINE PROCESS IN ST. CLOUD, MINNESOTA

By C. L. Ehrhart

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The ammonia-chlorine process was first discovered in 1907, but it was only recently that it began to receive the attention which such a valuable process deserves. It was several years after its discovery that it was first recognized for its germicidal value, but it was not used in water treatment until 1915 when Race introduced it at Ottawa, Canada. Another ten years elapsed before the system began to receive general attention and the main advance in its use has taken place within the last three years. The process began to receive attention in Minnesota about two years ago and St. Cloud installed an ammoniator in September, 1930.

## TREATMENT PROCESS

The water supply of St. Cloud is taken from the Mississippi River. Low lift pumps discharge the raw water into an aerator of the tank type, perforated with small holes spaced 1 inch apart which allow the water to trickle to the collecting basin beneath. The effluent from the collecting tank is divided into two streams passing through cast iron pipes to two mixing chambers. From the mixing chambers, the water passes to covered settling basins having a normal retention period of about five hours. The settled water passes from the basins to four filters, each having a rated capacity of 900,000 gallons per day. The filter effluent is collected into a clear well of 240,000 gallons capacity. From this clear well the water passes through domestic pumps into the distribution system. The anhydrous ammonia required is fed into the raw water lines at a point ahead of the aerator tank. This insures thorough mixing. Our first experiment delivered the ammonia into the tank beneath the aerator, but this was not satisfactory as the ammonia was not distributed evenly. Chlorine is fed into the pipe lines leading from the aerator tank to the mixing chambers. The alum, necessary for flocculation, is fed at the head

of the mixing trough. During the warmer months of the year, when taste or odors are encountered, activated carbon is fed into the settling basins about 75 feet ahead of the filters. No other treatment of any kind is being used at the St. Cloud plant.

In February, 1931, after nearly six months trial of the ammonia-chlorine process, the writer delivered a paper on this process at a meeting of the Minnesota Water Works Conference, in which he stated:

Prior to August, 1930, Chlorine was the only purifying agent used and this was applied at the filter effluent. A residual of about 0.08 was maintained at a tap in the pump room. However, the raw water was found to be subject to heavy pollution at times, with a B. coli index of 10,000 per 100 cc. which is the limit allowed by the U. S. Treasury Department standard for effluent chlorination alone. In order to secure better protection and a greater factor of safety against this load, it was decided to pre-chloriate and reduce the bacterial count so that the effluent chlorination would not be subject to overloads.

Accordingly, a second chlorinator was put into operation, feeding the chlorine solution into the collecting tank of the aerator. This served to lower the count of the settled water considerably but at the expense of a very high chlorine dosage. To lower this cost and possibly reduce the bacterial count still further, it was decided to experiment with the chlorine-ammonia process. The fact that it was claimed that by the use of this process, higher residuals could be maintained without taste was also a factor in this decision.

An ammoniator was secured and anhydrous ammonia was fed into the aerator tank, chlorine being introduced into the pipe lines between the tank and the mixing chambers and also into the filter effluent as formerly. Since the week of September 26, this system of purification has been followed. . . .

The turbidity of the raw water during the period of these experiments was very low, varying from 9 in August to 5 p.p.m. in December. The color was as high as 65 p.p.m. in September, but dropped gradually to 22 in January. The highest bacterial count at 37½°C. was 1400 per cubic centimeter in August and the lowest 250 in November and December. The raw water samples were not colon free at any time. The pH was constant throughout the period.

During the period from August 1 to September 4 when chlorine alone was used, the raw water was given a dosage of two full parts per million and the bacteria in the settled water was reduced to about 40 percent of the raw water count. For the first two weeks no settled water samples were colon free, but after that time some of the samples were free. The residual chlorine in the settled water was maintained at 0.5 p.p.m.

The filters further reduced the count to about 60 percent of the settled water count. As in the settled water, the filter effluent showed no colon free samples during the first two weeks, but after that period the percentage followed closely that of the settled water. At no time did the effluent water show any trace of chlorine.

To the filtered water, a final dose of chlorine of about 0.5 p.p.m. was added.

After passing through the clear well, samples were taken at the taps on the discharge side of the pump. These samples showed a turbidity of zero, a color of less than 0, a pH between 7.0 and 7.1, a chlorine residual of about 0.08 and an average bacterial count of 3. Quite naturally all tap samples were colon free.

Since the change was made to the chlorine-ammonia system, the raw water has been treated with about 0.36 p.p.m. of ammonia and from 0.5 to 0.6 p.p.m. of chlorine. The raw water count during this period has averaged 440 per cubic centimeter with no colon free samples, while the settled water average is 14 per cubic centimeter a little over 3 percent of the raw water average. The colon free samples during this period showed two weeks 75 percent free, two weeks 99 percent free and eleven weeks 100 percent free. Chlorine residuals in the settled water averaged between 0.3 and 0.35 p.p.m.

During the first six weeks of this treatment, the filter effluent samples carried higher bacterial counts than the settled water, showing that the filters were polluted from previous excessive loadings. After six weeks, all effluent samples were lower in count than settled water samples, which is evidence that the filters required that length of time to become thoroughly sterilized. During a fifteen week period, three weeks showed 99 percent of the effluent samples to be colon free and twelve weeks showed 100 percent free. During the entire period no residual chloramines have passed through the filters, although we expected to find some residual, particularly after the filter became sterile.

To the filter effluent, a final dosage of chlorine averaging between 0.25 and 0.30 p.p.m. was added and the tap water has shown about the same residual chloramine. The turbidity of the tap water was zero, the average color 9 and average count 2½ per cubic centimeter. The pH varied inversely as the alum used. The colon free samples were as before, 100 percent.

Samples taken at various taps on the distribution system have shown practically the same chloramine residual as at the pumps in all cases where the water reached the top within a few hours after leaving the plant. Other taps further removed from the plant, where it took a longer time for the water to reach, showed lower residuals, but even the most remote dead ends showed at least a trace. Water drawn from the pump taps at the plant and allowed to stand in the open carried residuals for three days before finally disappearing. In spite of this high residual in the system no chlorine or phenol tastes have been noticeable, although other tastes have been noticed particularly during the first two weeks of the chlorine-ammonia treatment, but this may have been partially due to the fact that the basins and filters were polluted by previous overloads. At the present time the basins and filters are practically sterile.

## USE OF ACTIVATED CARBON

Shortly after the above was written in 1931, our chemist began getting residuals on the filter effluent. These residuals, while small at first, gradually increased to a point where post chlorination was found to be unnecessary and was consequently eliminated. It was

also discovered in the spring of 1931 that the ammonia-chlorine process would not prevent all tastes and odors to which the water supply at St. Cloud was subject. An excess of cyclotella caused a distinctly fishy taste and to overcome this taste, plant experiments were started in the use of activated carbon, as preliminary laboratory experiments had proven that activated carbon would take out this taste. Our first method of application of carbon was made by mixing the carbon with water and applying this liquid directly into the filter at periods of about eight hours. Afterwards the applications were made at periods of four, two, and one hour intervals; which were gradually decreased until applications were being made each fifteen minutes. This led us to believe that the continuous feeding of carbon would be the best method and equipment was purchased to enable us to make the application in this manner.

Our present equipment consists of a type "O" W and T continuous feeding machine which ejects the mixture of carbon and water into a galvanized iron tank. The water level in this tank is maintained by a secondary water line controlled by a float valve. The mixture is drawn off from this tank by a small centrifugal pump which discharges it into pipe lines. This enables us to make the actual application at any point desirable. Our experience in feeding directly to the filters showed us that the filters matted rapidly, requiring frequent back washing. To overcome this matting of the filters our next experiment in continuous feeding was made by delivering the carbon to the outlet of the settling basins. This, however, still caused too much matting of filters so that now the carbon is applied a considerable distance ahead of the filters. This allows most of the carbon to settle out into the settling basins and what little goes over on to the filters does not seriously affect the filter runs.

The use of this activated carbon has served affectively to eliminate obnoxious tastes and odors. However, it also serves to complicate our method of sterilization as the carbon acts as a de-chlorinator. Oddly enough this dechlorination does not take place before the water passes the filters, but occurs in the passage through the filters. Therefore, it is necessary, at times when the carbon treatment is being used heavily, to give the filter effluent a small post-chlorination treatment, generally about 0.1 p.p.m. This brings the final residuals to about 0.15 or 0.20 p.p.m. In the winter months, when no carbon is being used, all post-chlorination is eliminated.

## AMMONIA-CHLORINE RATIOS

At the time the ammonia-chlorine process was installed in St. Cloud, the proportion of chlorine to ammonia was set at 2 to 1 simply for the reason that the experience of others seemed to indicate that this was about the correct proportion. However, it was our desire to use the most effective proportion and accordingly we ran some experiments to determine the correct one. The first experiments were run in the winter time when the raw water was subject to little, if any, change. By feeding a given amount of chlorine and then lowering the amount of ammonia it was possible to determine by the amount of residual when the correct proportions were reached. This was found to be about 7 to 1 rather than 2 to 1 which we had formerly used. When the ammonia was reduced to a lower ratio, the residuals dropped immediately, but when the ammonia was increased no particular difference in the residuals were noted. Later we checked this during the warmer months of the year with the same results.

Baker and Schmelkes in their pamphlet on the Ammonia-Chlorine process, state that

> The overwhelming majority of installations of the ammonia-chlorine process are made for any one or more of the following reasons:
> Prevention of taste development
> Prevention of aftergrowths
> Prevention of algae
> Ability to carry a high residual without chlorinous taste or odor
> Ability to carry a residual throughout a system to protect the system from pollution subsequent to chlorination or to prevent aftergrowths in open reservoirs, etc.

## INCIDENTAL BENEFITS

In St. Cloud, the introduction of the ammonia-chlorine process has served to give complete relief from some of the above mentioned troubles, but not from all. The process does not prevent the development of all tastes, for in our case it was necessary to use activated carbon in addition to the ammonia-chlorine process. However, it does prevent the taste of free chlorine which had bothered us considerably before the introduction of the process. If residuals above 0.25 or 0.30 are carried, the process sets up a taste, not chlorinous in character, however. By keeping the residuals down to 0.20 p.p.m. this taste entirely disappears and 0.20 p.p.m. will serve just as well as higher residuals.

The ammonia-chlorine process is particularly effective in the prevention of aftergrowths and algae. We have had no trouble with aftergrowths in mains and the algae in the raw water are reduced about 95 percent or better before it reaches the filters. There is no unwanted action taking place in the settling basins at the St. Cloud plant, the sediment on the bottom being inert and inoffensive where formerly it was gaseous and obnoxious. The present system enables the water department to carry and maintain a residual throughout the grid iron system as a protection against subsequent pollution. Where the water reaches the distribution point within an hour or two after being pumped, the residuals are practically the same as at the plant and even remote dead ends show trace of residuals.

In the St. Cloud plant, we have been able through careful experiments, to discover other benefits which to the best of our knowledge have never been touched upon in any of the articles on the ammonia-chlorine process. Race, in his experiments with the process, found that the addition of ammonia destroyed any bleaching property of "bleach." In other words, the ammonia-chlorine process stopped any oxidation which the chlorine alone might have carried on. Algae with their attendant tastes and odors undoubtedly thrive under conditions of low oxidation and are destroyed by high oxidation. Therefore, it occurred to us that if the benefits of free chlorine could be combined with the benefits of the ammonia-chlorine process, better results would be obtained than with either process alone. Assuming that the proportion of 7 to 1 was correct for securing the highest residual with the ammonia-chlorine process, we proceeded to raise the proportion of chlorine until it became 10 or 12 to one in order to obtain some free chlorine. This ratio did not seem to affect our residuals any and we naturally assumed that the excess chlorine was being used as an oxidizing agent. This conclusion was further borne out by the fact that we were able to reduce our alum dosage and still hold the color to a low point. In our case, the alum requirements vary with the color removed rather than with the turbidity, the finished water having a color about 8 to 10 p.p.m. In order to check on the oxidizing effect of the chlorine, we tried the following experiment. Leaving the chlorinator set in one position we increased the ammonia until the proportions were about 7 to 1. The bacterial count and the color increased and the tap water developed a musty odor, but no taste. By dropping the proportion of ammonia back to a 1 to 11 ratio, these conditions disappeared and

the water became the same as before the change in proportion. This confirmed our belief that with an excess of chlorine an oxidizing and bleaching effect takes place and that this helps to hold down the bacterial count and to eliminate odors and also takes out a certain amount of color with a consequent saving in the cost of alum. However, this process might not work out to advantage in all water supplies as the presence of oil or gas house wastes would probably throw down chlorine-phenol tastes. The raw water supply coming into the St. Cloud plant is evidently free from oils which might combine with free chlorine to set up phenol taste as no such taste has developed even when an excess of free chlorine was fed in the pre-treatment and free chlorine used as post treatment. In our case the saving in cost has been considerable and we expect to continue with it unless prevented by phenols.

The bacterial reduction which has taken place in the settling basins has been so great that the settled water is, at all times, well within the U. S. Treasury Department standard for drinking water supplies. Therefore, the filters have had very little work to do on account of this low bacterial load. This has been a great aid in reducing the wash water required to back-wash the filters. Instead of giving the filters complete back-washing each time the loss of head reaches the maximum, we have simply broken or bumped the filters. This is done by closing the filter effluent and opening the wash line. This stirs up the top of the filter and allows another run equal in length of time to the runs obtained by complete back-washing. No water is lost by this method and the filters are generally broken about three times before being given a regular back-wash to the sewer. Our average wash water when carbon is being used is about 2 percent and when no carbon is being used about 1 percent.

Our filters were originally built to handle a heavy bacterial load, the sand thickness being about 30 inches. However, on account of the quality of the water coming on to the filters, we felt that there was more sand than necessary and consequently we removed a foot of sand on each of two filters. Following this, we checked the quality of the filter effluent from each filter and found that there was absolutely no difference in the quality of water coming from those having 30 inches of sand and those having 18 inches of sand. However, there is a vast difference in the rate of flow, the filters having the smaller amount of sand being capable of delivering 50 to 100 percent more than those having the regulation amount of sand. These results

were obtained in experimental runs to determine the flow rates as it has never been necessary in this plant to filter above the rated capacity. We feel, though, that when it does become necessary we can obtain much greater flow than the rated capacity. This will prevent the necessity of spending additional funds for increased filter capacity. We believe that other water plants could obtain equally good results by the use of this method. If such a practice were carried out in general, it would make a great saving throughout the country by lowering the cost of new filter units and delaying, in many cases, the necessity of additional units.

*(Presented before the Minnesota Section meeting, September 15, 1932.)*

# THE MOST PROBABLE NUMBERS OF B. COLI IN WATER ANALYSIS

By J. K. Hoskins

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The expression of the number of B. coli in samples of water from the results of analyses by the dilution method has been the subject of much discussion. Phelps (1) suggested the procedure of expressing the number as the reciprocal of the smallest portion in a geometrical series of dilutions which gives a positive test for B. coli always assuming that the dilutions of the sample are such that at least one portion of the series gives a negative result. This "B. coli index," although readily calculated, is now generally recognized as an approximation. Its application becomes confusing when inconsistencies or so-called "skips" occur in the sequence or position of negative observations. Further difficulties are encountered in the estimation of the B. coli index whenever more than one observation is made at a given dilution.

When an apparently anomalous, but nevertheless rationally probable, case occurs wherein a negative result is obtained in a dilution between two positives, then by this procedure the positive observation of the higher dilution is interchanged with the negative and the index of this newly arranged series stated in the usual way. Thus, as explained in "Standard Methods for the Examination of Water and Sewage," 1925 edition, the interpretation of certain typical cases is as follows:

| B. COLI IN | | | B. COLI INDEX | |
|---|---|---|---|---|
| 10 cc. | 1 cc. | 0.1 cc. | Per 1 cc. | Per 100 cc. |
| + | − | − | 0.1 | 10 |
| + | + | − | 1.0 | 100 |
| + | − | + | 1.0 | 100 |

However, where a negative precedes two positives in higher dilutions, also a rationally probable case, no method of interpretation is

provided. Moreover, where more than one equal portion of the sample is inoculated into fermentation tubes, such as five 10 cc. portions, for instance, as required in the Treasury Department Standard, the B. coli index cannot be determined in this manner.

In any case, it is now generally agreed that the most probable number of B. coli is the proper interpretation of the analytical result by the fermentation tube method and that this most probable number cannot be found by the simple expedient of taking the reciprocal of the smallest portion of the sample which shows gas formation. In fact, a considerable error may be introduced when the B. coli index is determined by this simplified procedure.

Let it be assumed, for instance, that three portions of a sample, 10, 1, and 0.1 cc. respectively, were inoculated into lactose broth and that only the 10 cc. and the 0.1 cc. portions proved positive, an anomalous case not infrequent in routine work. Following the rule given in "Standard Methods," the B. coli would be interpreted as 1 per cc. or the B. coli index would be 100 per 100 cc. of sample. By a method which will presently be discussed, it can be shown readily that the most probable number is 95 per 100 cc., so that the two methods of computation in this anomalous case give substantially the same result.

Again, let it be assumed that in the geometric series in question, B. coli occurred only in the 10 cc. and 1 cc. portions. The B. coli index in this case is 100 per 100 cc. as before. The most probable number, however, is 240 per 100 cc. The B. coli index in this frequently observed case does not correspond, even approximately, to the more nearly correct most probable number.

McCrady (2) (3) first called attention to the more accurate interpretation of results of such bacteriological analyses, developed the formula for expression of the probable number and later, employing the suggestion of Wolman and Weaver (4) for the practical simplification of his formula, prepared extensive tabulations of the probable numbers corresponding to the geometric dilution series results most frequently encountered in practice. In the meantime, Stein (5) (6) (7) (8) (9) and Greenwood and Yule (10), working independently, proposed other formulae for the solution of the problem. Reed (11), following the reasoning of Greenwood and Yule, has shown that, as applied to the B. coli determinations, the probability curve assumes the form

$$y = \frac{1}{a}\left[(1 - e^{-N_1\lambda})^p(e^{-N_1\lambda})^q\right]\left[(1 - e^{-N_2\lambda})^r(e^{-N_2\lambda})^s\right]$$

$$\left[(1 - e^{-N_3\lambda})^t(e^{-N_3\lambda})^u\right]\left[\ldots\ldots\ldots\ldots\right] \qquad (1)$$

where $N_1\ N_2\ N_3 \ldots$ are the sizes of portions examined in cubic centimeters

$p, r, t \ldots$ are the numbers of portions of respective sizes giving positive tests for B. coli.

$q, s, u \ldots$ are the numbers of portions of corresponding sizes giving negative tests for B. coli

$\lambda$ = concentration of B. coli per cubic centimeter

$y$ = the probability of occurrence of the particular result, if the concentration from which the sample was drawn was $\lambda$

$e$ = base of Naperian logarithms = 2.7182818....

$a$ = a constant for any particular set of observations, the determination of the value of which may, therefore, be omitted in routine computation of $\lambda$

Thus, in a series where the B. coli determination gives

| 10 cc. | 10 cc. | 10 cc. | 10 cc. | 10 cc. | 1 cc. | 0.1 cc. |
|---|---|---|---|---|---|---|
| + | + | + | − | − | + | − |

$N_1 = 10 \quad p = 3 \quad q = 2$

$N_2 = 1 \quad r = 1 \quad s = 0$

$N_3 = 0.1 \quad t = 0 \quad u = 1$

and, substituting these values in equation (1), the probability curve for this set of determinations is defined by the equation:

$$y = \frac{1}{a}(1 - e^{-10\lambda})^3(e^{-10\lambda})^2(1 - e^{-\lambda})(e^{-\lambda})^0(1 - e^{-0.1\lambda})^0(e^{-0.1\lambda})$$

or

$$ay = (1 - e^{-10\lambda})^3(1 - e^{-\lambda})(e^{-10\lambda})^2(e^{-0.1\lambda}) \qquad (2a)$$

The mode of the curve, and hence the most probable number of B. coli for the series, is determined by finding that value of $\lambda$ which when substituted in the established probability equation (2), will make $y$ a maximum.

It will be observed that the general equation (1) covers any possible combination of analytical results, regardless of the number of tubes, the number of dilutions or the amounts of the dilutions whether or not in geometric series.

The solution of this general equation (1) for the value of $\lambda$ is quite formidable, but is not especially difficult by the method of trial and error when logarithms are employed. Taking logarithms of both sides, the equation becomes:

$$\log ay = p \log \left(1 - e^{-N_1\lambda}\right) + q \log \left(e^{-N_1\lambda}\right) + r \log \left(1 - e^{-N_2\lambda}\right) + s \log \left(e^{-N_2\lambda}\right) + t \log \left(1 - e^{-N_3\lambda}\right) + u \log \left(e^{-N_3\lambda}\right) + \ldots \quad (3)$$

As the terms log $(1\text{-}e^{-N\lambda})$ and log $(e^{-N\lambda})$ occur throughout, values of these functions once determined for various values of $N$ and $\lambda$ can be readily substituted in the general equation, each multiplied by the corresponding proper values of $p, q, r, s, t, u$.....respectively, and the resulting products added. Values of both of these functions are always less than 1, therefore, their logarithms have negative characteristics. Accordingly, the summation of the terms of equation (3), that is, the log of $ay$, will always have a negative characteristic or, in other words, $ay$ will be less than unity. Therefore, in substituting values of $\lambda$ (the concentration of bacteria per cubic centimeter) in the probability equation, it is only necessary to select that value of $\lambda$ which will make the sum of the logarithms, with its characteristic included, a maximum number.

By the use of the appended tables, the most probable number of any set-up of dilution results may be determined correctly to two significant figures. These logarithmic values have been computed by seven place logarithm tables and the figures entered to the nearest five places which is believed sufficiently accurate for most computations. For simplicity the negative part of the characteristic $(-10)$ is omitted from the values in the tables. The true statement of the function in each instance is to be understood to include this negative term. In combinations of results where the value of $N\lambda$ is greater than that to be found in the tables, the value of the function $(-e^{-N\lambda})$ is very nearly zero. Hence, the function $(1-e^{-N\lambda})$ in such case will be very nearly unity and log $(1-e^{-N\lambda})$ will be nearly zero and can be disregarded for practical purposes. This method of determining the most probable number is readily explained by a few examples.

(1) In the analytical result cited above, assume for example, trial

values of $\lambda$ of 0.11, 0.12, and 0.13. From the tables, select the proper log values for each of the functions in the established probability equation (2a) and multiply each by its proper power exponent. The summation of these respective products will be the log of *ay*, corresponding to the assumed value of $\lambda$. The detailed procedure is illustrated as follows:

| | | $\lambda = 0.11$ | $\lambda = 0.12$ | $\lambda = 0.13$ |
|---|---|---|---|---|
| $3 \log (1-e^{-10\lambda})$ | $= 3 \times 9.82421 =$ | 29.47263 | 29.53308 | 29.58543 |
| $\log (1-e^{-\lambda})$ | $=$ | 9.01773 | 9.05338 | 9.08602 |
| $2 \log (e^{-10\lambda})$ | $= 2 \times 9.52228 =$ | 19.04456 | 18.95770 | 18.87084 |
| $\log (e^{-0.1\lambda})$ | $=$ | 9.99522 | 9.99479 | 9.99435 |
| $\log ay$ | $=$ | 67.53014 | 67.53895 | 67.53664 |

The log of *ay* being greatest when $\lambda = 0.12$ the most probable number of B. coli per cubic centimeter is 0.12, or 12 per 100 cc. The multiplication of the selected values of log $(e^{-N\lambda})$ by the power exponent may be avoided frequently by first combining all exponents and selecting this corresponding value of the function from the table. Thus in the example above, $\log (e^{-10\lambda})^2 = \log (e^{-20\lambda})$ and from the table where $\lambda = 0.12$, $\log (e^{-2.4}) = 8.95769$. In such cases care must be exercised to compute the proper value of the characteristic.

(2) Assume the following analytical result:

| *1 cc.* | *0.1 cc.* | *0.01 cc.* | *0.001 cc.* |
|---|---|---|---|
| 5+ | 6+ | 4+ | 0+ |
| 0− | 1− | 6− | 8− |

The probability equation for this result would be:

$$ay = (1 - e^{-\lambda})^5(1 - e^{-0.1\lambda})^6(1 - e^{-0.01\lambda})^4(e^{-0.1\lambda})(e^{-0.01\lambda})^6(e^{-0.001\lambda})^8$$

Substituting values of $\lambda$ =

| | | $\lambda = 26$ | $\lambda = 27$ | $\lambda = 28$ | $\lambda = 29$ |
|---|---|---|---|---|---|
| $5 \log(1-e^{-\lambda})$ | = | 0.0 | 0.0 | 0.0 | 0.0 |
| $6 \log(1-e^{-0.1\lambda})$ | = | 59.79888 | 59.81874 | 59.83650 | 59.85252 |
| $4 \log(1-e^{-0.01\lambda})$ | = | 37.43896 | 37.49620 | 37.55108 | 37.60380 |
| $\log(e^{-0.1\lambda})$ | = | 8.87083 | 8.82740 | 8.78398 | 8.74055 |
| $6 \log(e^{-0.01\lambda})$ | = | 59.32248 | 59.29644 | 59.27040 | 59.24436 |
| $8 \log(e^{-0.001\lambda})$ | = | 79.90968 | 79.90616 | 79.90272 | 79.89928 |
| $\log ay$ | = | 245.34083 | 245.34494 | 245.34468 | 245.34051 |

The maximum total is, in this instance, obtained when the substituted value of $\lambda$ is 27 and the most probable number is therefore, 27 per cubic centimeter.

$Log\ e^{-N\lambda}$

| $\lambda$ \ $N$ = | 0.1 | 0.01 | 0.001 | 0.0001 | 0.00001 |
|---|---|---|---|---|---|
| 10 | 9.56,571 | 9.95,657 | 9.99,566 | 9.99,957 | 9.99,996 |
| 11 | 9.52,228 | 9.95,223 | 9.99,522 | 9.99,952 | 9.99,995 |
| 12 | 9.47,885 | 9.94,788 | 9.99,479 | 9.99,948 | 9.99,995 |
| 13 | 9.43,542 | 9.94,354 | 9.99,435 | 9.99,944 | 9.99,994 |
| 14 | 9.39,199 | 9.93,920 | 9.99,392 | 9.99,939 | 9.99,994 |
| 15 | 9.34,856 | 9.93,486 | 9.99,349 | 9.99,935 | 9.99,993 |
| 16 | 9.30,513 | 9.93,051 | 9.99,305 | 9.99,931 | 9.99,993 |
| 17 | 9.26,170 | 9.92,617 | 9.99,262 | 9.99,926 | 9.99,993 |
| 18 | 9.21,827 | 9.92,183 | 9.99,218 | 9.99,922 | 9.99,992 |
| 19 | 9.17,484 | 9.91,748 | 9.99,175 | 9.99,917 | 9.99,992 |
| 20 | 9.13,141 | 9.91,314 | 9.99,131 | 9.99,913 | 9.99,991 |
| 21 | 9.08,798 | 9.90,880 | 9.99,088 | 9.99,909 | 9.99,991 |
| 22 | 9.04,455 | 9.90,446 | 9.99,045 | 9.99,904 | 9.99,990 |
| 23 | 9.00,112 | 9.90,011 | 9.99,001 | 9.99,900 | 9.99,990 |
| 24 | 8.95,769 | 9.89,577 | 9.98,958 | 9.99,896 | 9.99,990 |
| 25 | 8.91,426 | 9.89,143 | 9.98,914 | 9.99,891 | 9.99,989 |
| 26 | 8.87,083 | 9.88,708 | 9.98,871 | 9.99,887 | 9.99,989 |
| 27 | 8.82,740 | 9.88,274 | 9.98,827 | 9.99,883 | 9.99,988 |
| 28 | 8.78,398 | 9.87,840 | 9.98,784 | 9.99,878 | 9.99,988 |
| 29 | 8.74,055 | 9.87,406 | 9.98,741 | 9.99,874 | 9.99,987 |
| 30 | 8.69,712 | 9.86,971 | 9.98,697 | 9.99,870 | 9.99,987 |
| 31 | 8.65,369 | 9.86,537 | 9.98,654 | 9.99,865 | 9.99,987 |
| 32 | 8.61,026 | 9.86,103 | 9.98,610 | 9.99,861 | 9.99,986 |
| 33 | 8.56,683 | 9.85,668 | 9.98,567 | 9.99,857 | 9.99,986 |
| 34 | 8.52,340 | 9.85,234 | 9.98,523 | 9.99,852 | 9.99,985 |
| 35 | 8.47,997 | 9.84,800 | 9.98,480 | 9.99,848 | 9.99,985 |
| 36 | 8.43,654 | 9.84,365 | 9.98,437 | 9.99,844 | 9.99,984 |
| 37 | 8.39,311 | 9.83,931 | 9.98,393 | 9.99,839 | 9.99,984 |
| 38 | 8.34,968 | 9.83,497 | 9.98,350 | 9.99,835 | 9.99,984 |
| 39 | 8.30,625 | 9.83,063 | 9.98,306 | 9.99,831 | 9.99,983 |
| 40 | 8.26,282 | 9.82,628 | 9.98,263 | 9.99,826 | 9.99,983 |
| 41 | 8.21,939 | 9.82,194 | 9.98,219 | 9.99,822 | 9.99,982 |
| 42 | 8.17,596 | 9.81,760 | 9.98,176 | 9.99,818 | 9.99,982 |
| 43 | 8.13,253 | 9.81,325 | 9.98,133 | 9.99,813 | 9.99,981 |
| 44 | 8.08,910 | 9.80,891 | 9.98,089 | 9.99,809 | 9.99,981 |
| 45 | 8.04,567 | 9.80,457 | 9.98,046 | 9.99,805 | 9.99,980 |
| 46 | 8.00,225 | 9.80,022 | 9.98,002 | 9.99,800 | 9.99,980 |
| 47 | 7.95,882 | 9.79,588 | 9.97,959 | 9.99,796 | 9.99,980 |
| 48 | 7.91,539 | 9.79,154 | 9.97,915 | 9.99,792 | 9.99,979 |
| 49 | 7.87,196 | 9.78,720 | 9.97,872 | 9.99,787 | 9.99,979 |
| 50 | 7.82,853 | 9.78,285 | 9.97,829 | 9.99,783 | 9.99,978 |
| 51 | 7.78,510 | 9.77,851 | 9.97,785 | 9.99,779 | 9.99,978 |
| 52 | 7.74,167 | 9.77,417 | 9.97,742 | 9.99,774 | 9.99,977 |
| 53 | 7.69,824 | 9.76,982 | 9.97,698 | 9.99,770 | 9.99,977 |
| 54 | 7.65,481 | 9.76,548 | 9.97,655 | 9.99,765 | 9.99,977 |
| 55 | 7.61,138 | 9.76,114 | 9.97,611 | 9.99,761 | 9.99,976 |

*Log* $(1-e^{-N\lambda})$

| $\lambda$ = \ $N$ = | 0.1 | 0.01 | 0.001 | 0.0001 | 0.00001 |
|---|---|---|---|---|---|
| 10 | 9.80,080 | 8.97,846 | 7.99,782 | 7.00,000 | 6.00,000 |
| 11 | 9.82,421 | 9.01,773 | 8.03,902 | 7.04,100 | 6.04,139 |
| 12 | 9.84,436 | 9.05,338 | 8.07,657 | 7.07,882 | 6.07,918 |
| 13 | 9.86,181 | 9.08,602 | 8.11,113 | 7.11,361 | 6.11,394 |
| 14 | 9.87,703 | 9.11,608 | 8.14,308 | 7.14,582 | 6.14,613 |
| 15 | 9.89,035 | 9.14,393 | 8.17,284 | 7.17,580 | 6.17,609 |
| 16 | 9.90,206 | 9.16,984 | 8.20,066 | 7.20,385 | 6.20,412 |
| 17 | 9.91,239 | 9.19,406 | 8.22,675 | 7.23,019 | 6.23,045 |
| 18 | 9.92,153 | 9.21,677 | 8.25,137 | 7.25,479 | 6.25,527 |
| 19 | 9.92,964 | 9.23,815 | 8.27,464 | 7.27,830 | 6.27,875 |
| 20 | 9.93,685 | 9.25,832 | 8.29,669 | 7.30,060 | 6.30,103 |
| 21 | 9.94,327 | 9.27,742 | 8.31,767 | 7.32,181 | 6.32,222 |
| 22 | 9.94,900 | 9.29,553 | 8.33,766 | 7.34,183 | 6.34,242 |
| 23 | 9.95,412 | 9.31,274 | 8.35,675 | 7.36,116 | 6.36,173 |
| 24 | 9.95,870 | 9.32,914 | 8.37,500 | 7.37,967 | 6.38,021 |
| 25 | 9.96,280 | 9.34,478 | 8.39,252 | 7.39,742 | 6.39,794 |
| 26 | 9.96,648 | 9.35,974 | 8.40,934 | 7.41,447 | 6.41,497 |
| 27 | 9.96,979 | 9.37,405 | 8.42,552 | 7.43,072 | 6.43,136 |
| 28 | 9.97,275 | 9.38,777 | 8.44,110 | 7.44,654 | 6.44,716 |
| 29 | 9.97,542 | 9.40,095 | 8.45,611 | 7.46,180 | 6.46,240 |
| 30 | 9.97,782 | 9.41,360 | 8.47,062 | 7.47,654 | 6.47,712 |
| 31 | 9.97,998 | 9.42,578 | 8.48,464 | 7.49,066 | 6.49,136 |
| 32 | 9.98,193 | 9.43,751 | 8.49,821 | 7.50,447 | 6.50,515 |
| 33 | 9.98,368 | 9.44,882 | 8.51,136 | 7.51,786 | 6.51,851 |
| 34 | 9.98,526 | 9.45,974 | 8.52,411 | 7.53,071 | 6.53,148 |
| 35 | 9.98,668 | 9.47,028 | 8.53,650 | 7.54,332 | 6.54,407 |
| 36 | 9.98,797 | 9.48,047 | 8.54,851 | 7.55,558 | 6.55,630 |
| 37 | 9.98,913 | 9.49,033 | 8.56,019 | 7.56,738 | 6.56,820 |
| 38 | 9.99,017 | 9.49,988 | 8.57,156 | 7.57,898 | 6.57,978 |
| 39 | 9.99,112 | 9.50,913 | 8.58,262 | 7.59,017 | 6.59,106 |
| 40 | 9.99,197 | 9.51,809 | 8.59,341 | 7.60,119 | 6.60,206 |
| 41 | 9.99,274 | 9.52,679 | 8.60,391 | 7.61,194 | 6.61,278 |
| 42 | 9.99,344 | 9.53,523 | 8.61,416 | 7.62,232 | 6.62,325 |
| 43 | 9.99,407 | 9.54,344 | 8.62,417 | 7.63,256 | 6.63,347 |
| 44 | 9.99,463 | 9.55,141 | 8.63,393 | 7.64,246 | 6.64,345 |
| 45 | 9.99,515 | 9.55,915 | 8.64,348 | 7.65,225 | 6.65,321 |
| 46 | 9.99,561 | 9.56,669 | 8.65,281 | 7.66,181 | 6.66,276 |
| 47 | 9.99,603 | 9.57,403 | 8.66,193 | 7.67,108 | 6.67,210 |
| 48 | 9.99,641 | 9.58,117 | 8.67,086 | 7.68,015 | 6.68,124 |
| 49 | 9.99,675 | 9.58,813 | 8.67,960 | 7.68,913 | 6.69,020 |
| 50 | 9.99,707 | 9.59,491 | 8.68,815 | 7.69,784 | 6.69,897 |
| 51 | 9.99,734 | 9.60,152 | 8.69,654 | 7.70,646 | 6.70,757 |
| 52 | 9.99,760 | 9.60,797 | 8.70,476 | 7.71,483 | 6.71,600 |
| 53 | 9.99,783 | 9.61,426 | 8.71,282 | 7.72,313 | 6.72,428 |
| 54 | 9.99,803 | 9.62,040 | 8.72,072 | 7.73,119 | 6.73,240 |
| 55 | 9.99,822 | 9.62,639 | 8.72,848 | 7.73,918 | 6.74,036 |

*Log* $e^{-N\lambda}$—Concluded

| $\lambda$ \ $N$ = | 0.1 | 0.01 | 0.001 | 0.0001 | 0.00001 |
|---|---|---|---|---|---|
| 56 | 7.56,795 | 9.75,680 | 9.97,568 | 9.99,757 | 9.99,976 |
| 57 | 7.52,452 | 9.75,245 | 9.97,525 | 9.99,752 | 9.99,975 |
| 58 | 7.48,109 | 9.74,811 | 9.97,481 | 9.99,748 | 9.99,975 |
| 59 | 7.43,766 | 9.74,377 | 9.97,438 | 9.99,744 | 9.99,974 |
| 60 | 7.39,423 | 9.73,942 | 9.97,394 | 9.99,739 | 9.99,974 |
| 61 | 7.35,080 | 9.73,508 | 9.97,351 | 9.99,735 | 9.99,974 |
| 62 | 7.30,737 | 9.73,074 | 9.97,307 | 9.99,731 | 9.99,973 |
| 63 | 7.26,394 | 9.72,639 | 9.97,264 | 9.99,726 | 9.99,973 |
| 64 | 7.22,052 | 9.72,205 | 9.97,221 | 9.99,722 | 9.99,972 |
| 65 | 7.17,709 | 9.71,771 | 9.97,177 | 9.99,718 | 9.99,972 |
| 66 | 7.13,366 | 9.71,337 | 9.97,134 | 9.99,713 | 9.99,971 |
| 67 | 7.09,023 | 9.70,902 | 9.97,090 | 9.99,709 | 9.99,971 |
| 68 | 7.04,680 | 9.70,468 | 9.97,047 | 9.99,705 | 9.99,970 |
| 69 | 7.00,337 | 9.70,034 | 9.97,003 | 9.99,700 | 9.99,970 |
| 70 | 6.95,994 | 9.69,599 | 9.96,960 | 9.99,696 | 9.99,970 |
| 71 | 6.91,651 | 9.69,165 | 9.96,917 | 9.99,692 | 9.99,969 |
| 72 | 6.87,308 | 9.68,731 | 9.96,873 | 9.99,687 | 9.99,969 |
| 73 | 6.82,965 | 9.68,297 | 9.96,830 | 9.99,683 | 9.99,968 |
| 74 | 6.78,622 | 9.67,862 | 9.96,786 | 9.99,679 | 9.99,968 |
| 75 | 6.74,279 | 9.67,428 | 9.96,743 | 9.99,674 | 9.99,967 |
| 76 | 6.69,936 | 9.66,994 | 9.96,699 | 9.99,670 | 9.99,967 |
| 77 | 6.65,593 | 9.66,559 | 9.96,656 | 9.99,666 | 9.99,967 |
| 78 | 6.61,250 | 9.66,125 | 9.96,613 | 9.99,661 | 9.99,966 |
| 79 | 6.56,907 | 9.65,691 | 9.96,569 | 9.99,657 | 9.99,966 |
| 80 | 6.52,564 | 9.65,256 | 9.96,526 | 9.99,653 | 9.99,965 |
| 81 | 6.48,221 | 9.64,822 | 9.96,482 | 9.99,648 | 9.99,965 |
| 82 | 6.43,879 | 9.64,388 | 9.96,439 | 9.99,644 | 9.99,964 |
| 83 | 6.39,536 | 9.63,954 | 9.96,395 | 9.99,640 | 9.99,964 |
| 84 | 6.35,193 | 9.63,519 | 9.96,352 | 9.99,635 | 9.99,964 |
| 85 | 6.30,850 | 9.63,085 | 9.96,309 | 9.99,631 | 9.99,963 |
| 86 | 6.26,507 | 9.62,651 | 9.96,265 | 9.99,627 | 9.99,963 |
| 87 | 6.22,164 | 9.62,216 | 9.96,222 | 9.99,622 | 9.99,962 |
| 88 | 6.17,821 | 9.61,782 | 9.96,178 | 9.99,618 | 9.99,962 |
| 89 | 6.13,478 | 9.61,348 | 9.96,135 | 9.99,613 | 9.99,961 |
| 90 | 6.09,135 | 9.60,913 | 9.96,091 | 9.99,609 | 9.99,961 |
| 91 | 6.04,792 | 9.60,479 | 9.96,048 | 9.99,605 | 9.99,960 |
| 92 | 6.00,449 | 9.60,045 | 9.96,004 | 9.99,600 | 9.99,960 |
| 93 | 5.96,106 | 9.59,611 | 9.95,961 | 9.99,596 | 9.99,960 |
| 94 | 5.91,763 | 9.59,176 | 9.95,918 | 9.99,592 | 9.99,959 |
| 95 | 5.87,420 | 9.58,742 | 9.95,874 | 9.99,587 | 9.99,959 |
| 96 | 5.83,077 | 9.58,308 | 9.95,831 | 9.99,583 | 9.99,958 |
| 97 | 5.78,734 | 9.57,873 | 9.95,787 | 9.99,579 | 9.99,958 |
| 98 | 5.74,391 | 9.57,439 | 9.95,744 | 9.99,574 | 9.99,957 |
| 99 | 5.70,048 | 9.57,005 | 9.95,700 | 9.99,570 | 9.99,957 |
| 100 | 5.65,706 | 9.56,571 | 9.95,657 | 9.99,566 | 9.99,957 |

*Log* $(1-e^{-N\lambda})$—Concluded

| $\lambda$ = \ $N$ = | 0.1 | 0.01 | 0.001 | 0.0001 | 0.00001 |
|---|---|---|---|---|---|
| 56 | 9.99,839 | 9.63,225 | 8.73,609 | 7.74,695 | 6.74,819 |
| 57 | 9.99,854 | 9.63,796 | 8.74,356 | 7.75,465 | 6.75,587 |
| 58 | 9.99,868 | 9.64,355 | 8.75,089 | 7.76,215 | 6.76,343 |
| 59 | 9.99,881 | 9.64,902 | 8.75,810 | 7.76,953 | 6.77,085 |
| 60 | 9.99,892 | 9.65,436 | 8.76,518 | 7.77,685 | 6.77,815 |
| 61 | 9.99,902 | 9.65,958 | 8.77,215 | 7.78,398 | 6.78,533 |
| 62 | 9.99,912 | 9.66,469 | 8.77,900 | 7.79,106 | 6.79,239 |
| 63 | 9.99,920 | 9.66,970 | 8.78,574 | 7.79,796 | 6.79,934 |
| 64 | 9.99,928 | 9.67,459 | 8.79,236 | 7.80,482 | 6.80,618 |
| 65 | 9.99,935 | 9.67,939 | 8.79,887 | 7.81,151 | 6.81,291 |
| 66 | 9.99,941 | 9.68,408 | 8.80,529 | 7.81,809 | 6.81,954 |
| 67 | 9.99,947 | 9.68,868 | 8.81,161 | 7.82,465 | 6.82,607 |
| 68 | 9.99,952 | 9.69,318 | 8.81,783 | 7.83,104 | 6.83,251 |
| 69 | 9.99,956 | 9.69,760 | 8.82,395 | 7.83,734 | 6.83,885 |
| 70 | 9.99,960 | 9.70,193 | 8.82,999 | 7.84,361 | 6.84,510 |
| 71 | 9.99,964 | 9.70,617 | 8.83,593 | 7.84,973 | 6.85,126 |
| 72 | 9.99,968 | 9.71,033 | 8.84,179 | 7.85,576 | 6.85,733 |
| 73 | 9.99,971 | 9.71,441 | 8.84,757 | 7.86,171 | 6.86,332 |
| 74 | 9.99,973 | 9.71,841 | 8.85,326 | 7.86,764 | 5.86,923 |
| 75 | 9.99,976 | 9.72,233 | 8.85,888 | 7.87,344 | 6.87,506 |
| 76 | 9.99,978 | 9.72,618 | 8.86,442 | 7.87,915 | 6.88,081 |
| 77 | 9.99,980 | 9.72,996 | 8.86,988 | 7.88,480 | 6.88,649 |
| 78 | 9.99,982 | 9.73,367 | 8.87,527 | 7.89,042 | 6.89,209 |
| 79 | 9.99,984 | 9.73,732 | 8.88,059 | 7.89,592 | 6.89,763 |
| 80 | 9.99,985 | 9.74,089 | 8.88,584 | 7.90,135 | 6.90,309 |
| 81 | 9.99,987 | 9.74,440 | 8.89,101 | 7.90,671 | 6.90,849 |
| 82 | 9.99,988 | 9.74,785 | 8.89,613 | 7.91,201 | 6.91,381 |
| 83 | 9.99,989 | 9.75,124 | 8.90,118 | 7.91,730 | 6.91,908 |
| 84 | 9.99,990 | 9.75,457 | 8.90,617 | 7.92,247 | 6.92,428 |
| 85 | 9.99,991 | 9.75,784 | 8.91,109 | 7.92,758 | 6.92,942 |
| 86 | 9.99,992 | 9.76,105 | 8.91,596 | 7.93,263 | 6.93,450 |
| 87 | 9.99,993 | 9.76,421 | 8.92,076 | 7.93,762 | 6.93,952 |
| 88 | 9.99,993 | 9.76,732 | 8.92,551 | 7.94,255 | 6.94,448 |
| 89 | 9.99,994 | 9.77,037 | 8.93,021 | 7.94,743 | 6.94,939 |
| 90 | 9.99,995 | 9.77,337 | 8.93,485 | 7.95,231 | 6.95,424 |
| 91 | 9.99,995 | 9.77,632 | 8.93,943 | 7.95,708 | 6.95,904 |
| 92 | 9.99,996 | 9.77,922 | 8.94,396 | 7.96,180 | 6.96,379 |
| 93 | 9.99,996 | 9.78,208 | 8.94,844 | 7.96,647 | 6.96,848 |
| 94 | 9.99,996 | 9.78,488 | 8.95,287 | 7.97,109 | 6.97,313 |
| 95 | 9.99,997 | 9.78,764 | 8.95,726 | 7.97,566 | 6.97,772 |
| 96 | 9.99,997 | 9.79,036 | 8.96,159 | 7.98,019 | 6.98,227 |
| 97 | 9.99,997 | 9.79,303 | 8.96,588 | 7.98,466 | 6.98,677 |
| 98 | 9.99,998 | 9.79,566 | 8.97,012 | 7.98,909 | 6.99,123 |
| 99 | 9.99,998 | 9.79,825 | 8.97,431 | 7.99,348 | 6.99,564 |
| 100 | 9.99,998 | 9.80,080 | 8.97,846 | 7.99,782 | 7.00,000 |

(3) For the analytical result:

| 10 cc. | 5 cc. | 2 cc. | 1 cc. |
|---|---|---|---|
| 6+ | 4+ | 2+ | 0+ |
| 1− | 8− | 5− | 8− |

the probability equation is written:

$$ay = (1 - e^{-10\lambda})^6(1 - e^{-5\lambda})^4(1 - e^{-2\lambda})^2(e^{-10\lambda})(e^{-5\lambda})^8(e^{-2\lambda})^5(e^{-\lambda})^8$$

Substituting values of $\lambda$:

| | | $\lambda = 0.11$ | $\lambda = 0.12$ | $\lambda = 0.13$ | $\lambda = 0.20$ |
|---|---|---|---|---|---|
| $6 \log(1-e^{-10\lambda})$ | = | 58.94526 | 59.06616 | 59.17086 | 59.62110 |
| $4 \log(1-e^{-5\lambda})$ | = | 38.50556 | 38.61744 | 38.71756 | 39.20320 |
| $2 \log(1-e^{-2\lambda})$ | = | 18.59106 | 18.65828 | 18.71948 | 19.03618 |
| $\log(e^{-10\lambda})$ | = | 9.52228 | 9.47885 | 9.43542 | 9.13141 |
| $8 \log(e^{-5\lambda})$ | = | 78.08912 | 77.91536 | 77.74168 | 76.52568 |
| $5 \log(e^{-2\lambda})$ | = | 49.52230 | 49.47885 | 49.43540 | 49.13140 |
| $8 \log(e^{-\lambda})$ | = | 79.61784 | 79.58304 | 79.54832 | 79.30512 |
| $\log ay$ | = | 332.79342 | 332.79798 | 332.76872 | 331.95409 |

In this case the maximum value of log $ay$ is obtained when $\lambda = 0.12$; therefore, the most probable number is 0.12 per cubic centimeter or 12 B. coli per 100 cc.

In determining the trial values of $\lambda$ to be used in any established equation it will be found helpful to estimate as nearly as may be, the correct probable value of $\lambda$ and then to select a series of at least three values at some distance apart grouped about the estimated figure and, by observation of the respective summations of terms, ascertain whether the true probable number falls within the assumed range. The assumption of $\lambda$ values can then be narrowed down until the true probable number is obtained.

In order to eliminate repeated computations for the series of dilutions most commonly employed in any laboratory, it will be found profitable to prepare a table of probable numbers of the combinations possible to be secured from such series.

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(10) GREENWOOD, M., AND YULE, G. UDNEY: On the statistical interpretation of some bacteriological methods employed in water analysis. Jour. of Hygiene, 16, 36–54 (July, 1917).

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Why use this method ?
Use the formula:

$$MPN = \frac{\text{Number of Positive Tubes}}{\sqrt{\left(\text{Number of ml. in neg. tubes}\right)\left(\text{Number of ml. in all tubes}\right)}}$$

## SYMPOSIUM ON WATER HAMMER, FRIDAY, JUNE 30, 1933

SESSIONS 9:30 A.M. AND 2:00 P.M., CHICAGO, ILL.

*Under the joint auspices A. S. M. E. Hydraulic Division and A. S. C. E. Power Division*

Presiding officer Mr. L. F. Harza.

Discussion led by Mr. Norman R. Gibson.

*Comparison of water hammer theory with recommended symbols, bibliography and summary of theory for simple conduits by Committee on water hammer*, Chairman, S. Logan Kerr, N. R. Gibson, Eugene E. Halmos, Lewis F. Moody, Ray S. Quick, Earl B. Strowger.

*Simplified derivation of water hammer formula*, L. F. Moody, Professor Hydraulic Engineering, Princeton University, Princeton, N. J.

*High head penstock design*, A. W. K. Billings, Vice-President, Brazilian Traction, Light & Power Co., Ltd., Rio de Janeiro, Brazil, S. A., and O. H. Dodkin, Hydraulic Engineer, Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil, F. Knapp, Asst. Hydraulic Engineer, Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil, Adolpho Santos, Jr., Asst. Hydraulic Engineer, Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil.

*Influence of water hammer on design of high head penstocks at the Drum Plant and Tiger Creek Plant*, Walter Dreyer, Asst. Chief Division of Civil Engineering, Pacific Gas & Electric Company, San Francisco, California.

*Computation of water hammer pressures in compound pipes*, Robert E. Glover, Engineer, U. S. Bureau of Reclamation, Denver, Colorado.

*Effects of surge tanks and surge tank risers on water hammer computations*, Eugene E. Halmos, Chief Engineer, Parklap Construction Corp., New York, N. Y.

*Surge control in centrifugal pump discharge lines*, Ray S. Quick, Chief Engineer, Pelton Water Wheel Co., San Francisco, California.

*Water hammer tests in Croton Lake Pumping Plant*, S. Logan Kerr, Water Works Engineer, Baldwin-Southwark Corporation, Philadelphia, Pa.

*Comparison of water hammer theory with recommended symbols, bibliography and summary of theory for simple conduits by Committee on water hammer*, Chairman, S. Logan Kerr, N. R. Gibson, Eugene E. Halmos, Lewis F. Moody, Ray S. Quick, Earl B. Strowger.

It has been recognized for some time by engineers concerned with the study of water hammer that many valuable contributions to technical literature have been made on this subject, but that many of the phases of this most important problem have not been adequately covered in English, or if such contributions have been made, the distribution of the information has been extremely limited. Recognizing this difficulty, a committee was appointed by the American Society of Mechanical Engineers to review the existing theory on water hammer, with a view to summarizing this theory, comparing the various methods employed, considering actual water hammer problems, computing the pressure variations by various methods outlined, and determining which theories would apply and which theories have been confirmed by actual experimentation.

From this study it was found that the subject of water hammer had been covered fully in regard to conduits of uniform thickness and diameter, but that data were lacking on the more involved problems of conduits having variable thickness and diameter, and those having branch pipes. Arrangements were made with various American engineers to present detailed treatises on these phases of water hammer at a symposium.

The committee, composed of Norman R. Gibson, Eugene E. Halmos, Lewis F. Moody, Ray S. Quick, Earl B. Strowger and S. Logan Kerr, Chairman, have prepared a report outlining the history of water hammer theory and the early contributions of Joukowsky and Allievi in regard to simple conduits of uniform thickness and diameter and classifying water hammer under five essential divisions.

*Case I—Conduits of uniform thickness and diameter (simple conduits).* This case covers many actual installations, and the committee found that the basic formulas of Allievi, N. R. Gibson, R. S. Quick and the Arithmetic Integration method published by N. R. Gibson are all in exact agreement for simple conduits. The charts of Allievi and Quick are included, which can be used for the rapid determination of the maximum pressure rise in simple conduits.

*Case II—Conduits of variable thickness and diameter (complex conduits).* The effect of reflection and transmission of pressure waves

at points where a change in thickness or diameter occur will affect materially the magnitude and shape of the pressure time relation, and will, in many cases, result in excess pressures much greater than result from the use of the theory for simple conduits.

*Case III—Conduits having branch pipes (compound conduits).* The reflection of waves from branch pipes and dead ends affects materially the maximum pressure surge, and the reflected waves must be considered if an accurate determination of water hammer is to be made in the various portions of the conduit.

*Case IV—Water hammer in pump discharge conduits.* This very important water hammer problem is dealt with in the committee report, but complete theory on this phase of water hammer is not yet available.

*Case V—Surge tanks.* The surge tank is studied in its relation to water hammer as distinguished from its function of regulating flow in the conduit. The effect of varying sizes of surge tanks on the water hammer conditions has been studied.

The committee has included a list of recommended symbols for water hammer computations to endeavor to avoid the confusion which now exists in comparing water hammer formulas. The recommended symbols and the symbols used in several previous important contributions are included in Appendix I of the committee report for reference.

A complete bibliography of water hammer publications is included as Appendix II for the benefit of those desiring to conduct further investigations and research. The committee has included an Appendix III, showing typical examples of water hammer problems and their solution, and has also reproduced convenient charts previously prepared for the determination of the maximum pressure rise and fall in simple conduits, a chart for the determination of the velocity of the pressure wave and diagrams illustrating the effect of non-uniform variation of discharge characteristics with respect to time, all of which affect the maximum pressure rise. In addition, seven papers have been prepared dealing with different aspects of the problem.

*Simplified derivation of water hammer formula*, L. F. Moody, Mem. A. S. M. E., Professor Hydraulic Engineering, Princeton University, Princeton, N. J.

This paper develops the essential water hammer formula, such as

the velocity of the pressure wave and the value of instantaneous water hammer by the use of Newton's second law of motion to present to American Engineers the classic formula for water hammer problems, in a different manner than employed in many other treatises. The successive phases of instantaneous water hammer phenomena are shown in illustrations to give a better conception of the essential elements of this problem.

*High head penstock design*, A. W. K. Billings, Vice-President, Brazilian Traction, Light & Power Co., Ltd., Rio de Janeiro, Brazil, S. A., and O.H. Dodkin, Hydraulic Engineer, Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil, F. Knapp, Asst. Hydraulic Engineer, Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil, Adolpho Santos, Jr., Asst. Hydraulic Engineer, Sao Paulo Tramway Light & Power Co., Sao Paulo, Brazil.

This joint paper represents the results of approximately eight years research and experimental work on high head penstocks, which has centered around the Serra do Cubatao Development of the Sao Paulo Tramway Light & Power Company in Brazil. A complete new method for high head penstock design has been outlined, based on this research work which emphasized the importance of considering accidental factors as the limiting feature of design rather than the conditions for normal governing, which would produce only moderate water hammer. The criteria for design of penstock, from the point of view of hydraulic conditions has been outlined in detail and the mechanical criteria of design are discussed extensively, taking up the importance of material characteristics, the variations which occur during manufacture, the types of pipe available, and methods of manufacture and construction insofar as it has a direct effect upon the safety of the completed conduit.

The theory of surges for penstocks of variable thickness and diameter is treated at length, and the complete formula is included together with numerical examples which permit engineers to apply this theory to any similar problem.

Of prime interest are the field tests which produced instantaneous water hammer on the full size penstock, and the comparison of the results of this field work with the theory presented in this paper, which considers the effect of partial reflection of water hammer waves at points where variations occur in thickness or diameter.

This paper includes a recommendation for a radically new design

of turbine penstock, which is arranged in such a manner that the reflections of waves are diffused throughout the length of the penstock, limiting materially the water hammer conditions, and resulting in a penstock which has an inverse taper from the intake to the turbine and effects considerable saving in material and cost.

The various stress theories are considered and comparisons are made of the formulas for determining stress and the theories of failure. The effect of rate and manner of stress application is considered, and descriptions are included of tests made on full size pipes to study the behavior of such pipes in comparison to the theory.

Means of protection are outlined in detail, and recommendations are made regarding inspection during manufacture and construction to insure the safety of the ultimate installation.

The use of an over pressure test on the completed penstock is recommended as a means of checking the theory of design and of the safety of the penstock. The paper offers a series of conclusions reached in regard to penstock design which has resulted from this extensive research and experimental program. The paper thus presents a comprehensive treatise on the design of penstocks in the light of present theory and experience.

*Influence of water hammer on design of high head penstocks at the Drum Plant and Tiger Creek Plant,* Walter Dreyer, Asst. Chief Division of Civil Engineering, Pacific Gas & Electric Co., San Francisco, California.

This paper outlines in general the practice of one of the large power companies on the West Coast in regard to water hammer conditions in high head penstocks insofar as the design and safety of the conduit is concerned. Two important developments are described, and the comparison made between the results of actual field tests for water hammer and the theoretical values upon which the penstock design was based. The essential design factors are included, together with the general allowances for stress in such conduits.

*Computation of water hammer pressures in compound pipes,* Robert E. Glover, Engineer, U. S. Bureau of Reclamation, Denver, Colorado.

This paper is of timely interest, since the methods outlined were employed in the design of the conduits for Boulder Dam Power Plant, which included in addition to variations in thickness and

diameter, branch pipes and dead ends in the conduit, resulting in a highly involved problem in water hammer determination. This paper outlines the theory used for the computation of water hammer in such conduits, and gives the methods of calculation, together with a typical example, and shows the means of determining, the water hammer pressures at different points in this compound conduit due to the cutting off of flow on the extremely large turbines. Comparative curves from other experimental investigations are included. This paper presents a rather novel method of attack on water hammer investigations in such difficult situations.

*Effect of surge tanks and surge tank risers on water hammer computations,* Eugene E. Halmos. Chief Engineer, Parklap Construction Corp., New York, N. Y.

In long conduits, particularly those supplying hydroelectric units, surge tanks are frequently employed to improve the speed regulation of the hydraulic turbines. The effect of these tanks on reducing water hammer and the required proportions of a surge tank to act as a complete relief for water hammer waves is discussed, and the essential theory for the determination of the pressure rise at the base of the surge tank has been translated in part from the later works of Allievi, and in part from a recent publication on surge tanks by Calame and Gaden in Switzerland.

Comparative examples are given, showing the effect on water hammer of the variations in size of the surge tank, whether located at the point of control of flow, or whether located at some intermediate point on the conduit. This paper brings to the attention of American engineers the necessity for the proper proportioning of surge tanks where their function primarily is to limit water hammer under critical conditions.

*Surge control in centrifugal pump discharge lines,* Ray S. Quick, Chief Engineer, Pelton Water Wheel Co., San Francisco, California.

This paper deals with the general problem of water hammer in pump discharge lines, and outlines, in addition, various means, including a new device, for limiting or controlling the water hammer frequently experienced in such installations. Curves are included, which show the tests conducted on 1200 feet head pumping plants supplying water to Boulder City built to house the Boulder Dam construction staff.

*Water Hammer tests in Croton Lake Pumping Plant*, S. Logan Kerr, Assoc. Member A. S. M. E., Water Works Engineer, Baldwin-Southwark Corporation, Philadelphia, Pa.

A description of extensive series of water hammer tests conducted on the Croton Lake Pumping Plant, which forms a part of the water supply system for New York City. The behavior of check valves under various operating conditions is given, together with the new method employed to eliminate water hammer and surge conditions which are experienced following the emergency tripping out of the motor driven centrifugal pumps. A description is given of the test methods employed, and the various apparatus used to record the simultaneous functioning of check valves, surge suppressors and other apparatus during emergency conditions. The paper includes typical charts showing the water hammer experienced under various conditions, and describes in detail the methods employed in interpreting the test data.

*Publication of papers*

Owing to the present conditions of financial distress, it was not possible to secure the publication of these papers and their discussions by the American Society of Mechanical Engineers, but arrangements were made to have the complete symposium published privately under the auspices of the Society. In order to defray the publication cost, a nominal charge is being made. The volume available in advance of the meeting contains only the papers, but a supplement will be issued following the meeting which will include all of the discussion both written and oral presented at the symposium.

Copies of the volume containing all symposium papers can be obtained from a special staff representative at the meeting, or after June 1, through application to the American Society of Mechanical Engineers, 29 W. 39th Street, New York City. A charge of $1.00 per copy will be made to members of the A. S. M. E., A. S. C. E. and A. W. W. A., and a charge of $1.50 to non-members.

## *CORRECTIONS*

To the Editor:

This is to call your attention to an error appearing in Vol. 24, No. 10, October, 1932, of The Journal page 1527, in the 3rd paragraph thereof, 4th line.

The three words "tenth of one" should be stricken out. The sentence containing these three words will then read as follows:

> "for a deduction of one dollar per gallon per minute for each per cent of efficiency . . . ."

Yours very truly,

Wm. F. Laase,

*Division Engineer, Department of Water Supply, Gas and Electricity, New York, N. Y.*

To the Editor:

In my paper on "Mistreatment of Water" in the April, 1933, issue of The Journal,

> table 1 appearing on page 495 showing the effect of treatment on public water supplies carries the notation in parenthesis (results in parts per million). This is in error as the results are reported in grains per gallon.

Yours very truly,

C. R. Knowles,

*Superintendent Water Service, Illinois Central System, Chicago, Ill.*

# ABSTRACTS OF WATER WORKS LITERATURE[1]

FRANK HANNAN

**Key: American Journal of Public Health, 12: 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.**

**Spokane Builds Artistic Water Tower.** ALEX LINDSAY. West. Constr. News & High. Bldr., 7: 9, 252–253, 1932. Water tower of most pleasing architectural design, with capacity of 1.25 m.g., was recently constructed in fine residential section of Spokane, Wash., to serve as storage and pressure-regulating reservoir for large district, at contract price of $81,283. It consists of flat-bottomed steel tank, 78 feet in diameter by 35 feet high, resting on 16-inch reinforced concrete slab, 84.5 feet above ground level, which is supported by series of rectangular concrete cells 12 feet square. Exterior wall of monolithic concrete construction surrounds tank and its supporting structure. Vertical lines are emphasized, to add to apparent height of tower, which stands 122 feet 8 inches high. Slip forms were used to produce perfect vertical lines and smooth surface and also to permit rapid completion of work. 2525 cubic yards of concrete in inner and outer walls were placed in 15 days. Water level is maintained by five automatic pumping units with combined capacity of 23,600 g.p.m. by means of original and unusual control devices designed in Water Department.—*Geo. C. Bunker.*

**Lewiston Filter Plant.** WILLIAM P. HUGHES. West. Constr. News & High. Bldr., 7: 9, 256, May 10, 1932. Lewiston, Idaho, rapid sand filtration plant has been in continuous operation since December, 1924. The four 1.5-m.g.d. filters were recently rebuilt, as sand and gravel had become badly mixed and considerable fine rock had lodged under umbrella strainer tops on underdrains. Average total cost per filter was $296.45; of which $205.17 was for labor, on basis of $0.50 per hour. Very complete cost analysis of work is given. Changes in chemical treatment of water are contemplated, so as to maintain pH of 6.6 in water entering filters and thus eliminate residual alumina; lime, or soda ash, will be added to filtered water to raise pH to about 8.4. Original operation control specified maintenance of pH of 7.4 during coagulation, by use of alum and lime; with result that filtered water contained 0.2 p.p.m.

[1] Vacancies on the abstracting staff occur from time to time. Members desirous of coöperating in this work are earnestly requested to communicate with the chief abstractor, Frank Hannan, 285 Willow Avenue, Toronto 8, Ontario, Canada.

residual alumina. Statistical summary for fiscal year of 1930–31 shows cost of purification as $0.01236, and total cost of water delivered to reservoir as $0.05414, per 1000 gallons.—*Geo. C. Bunker.*

**Sultan River Water Supply for Everett.** John W. Cunningham. West. Constr. News & High. Bldr., 7: 9, 257–262, May 10, 1932. Detailed description of 50-m.g.d. water supply project for Everett, Wash., which cost approximately $1,711,448 and was placed in service in October, 1930. From diversion dam on Sultan river water flows through single 54-inch creosoted continuous wood-stave pipe line 2058 feet long into unlined tunnel 7164 feet long and thence into Lake Chaplain. Present capacity of pipe line and tunnel is 90 m.g.d.; when latter is lined with concrete, its capacity will be increased to 125 m.g.d. Level of lake has been raised 16 feet by an earth filled dam to create storage of 1400 m.g., or enough to equalize 50-m.g.d. flow. This natural lake furnishes cheaply storage essential to take care of wide range in flow of Sultan river and to remove turbidity during flood stages. Ultimately, storage will be increased to 4500 m.g., to take care of flow of 100 m.g.d. At opposite end of lake from in-flow, is concrete-lined, no-pressure, outlet tunnel, 4415 feet long, with control tower at upper end, of 100-m.g.d. capacity. By-pass line of 36-inch Hume centrifugally-spun concrete pipe, 8094 feet long, with capacity of 37 m.g.d., is laid around lake, through which water may be drawn directly from river at times when, due to algae, or to semi-annual turn-over, quality of lake water may be inferior. From end of outlet tunnel, water flows by gravity through 52-inch pipe line to rather elaborate screening plant on summit of ridge about half-way between lake and Everett. Screening is necessary, lest any pulp-mill waste, ecsaping reservoir sedimentation, might reach general distribution system. Screening plant consists of concrete building 50 by 81 feet, provided with 1926 square feet of screening area made up of 36 6- x 6-foot screens of upward flow type. Extremely low screening velocity, of about 0.1 foot per second, is obtained. Channels, gates, and waste pipes are arranged for convenient operation and washing. Water for washing screens and for chlorinators is pumped by two 4-inch hydraulic rams into 15,000-gallon elevated tank. Cost of screening plant was about $500 per m.g.d. capacity. After screening, water is chlorinated. Chlorine solution is passed through limestone tower and resulting hypochlorous acid is believed to be less rapidly absorbed by organic matter and more efficient than chlorine. The ten principal contracts for project totalled $1,711,448.—*Geo. C. Bunker.*

**Okanogan Avenue Reservoir at Wenatchee.** George H. Miller. West. Constr. News & High. Bldr., 7: 9, 263–267, May 10, 1932. Detailed description of construction of covered reinforced concrete reservoir with capacity of 4 m.g.—*Geo. C. Bunker.*

**Hood Street Booster Station for Tacoma.** W. A. Kunigk. West. Constr. News & High. Bldr., 7: 10, 283–286, May 25, 1932. Project covers following units. (1) Reinforced concrete pumping station, designed along modernistic lines with tile ornaments, with capacity of 20 m.g.d., and equipped with three 12- by 12-in., single-stage, double-suction, motor-driven centrifugal pumps

of 5000 g.p.m. capacity. (2) Line of 42-inch, centrifugally-spun, reinforced concrete pipe, 19,580 feet long, between collecting basin of south Tacoma wells system and Hood Street reservoir. (3) Electric-welded 30-inch steel discharge pipe line to connect pump discharge header with distribution system. (4) Surge tank, to eliminate troubles resulting from air entering distribution system during operation of above reservoir. Total cost was estimated at $116,136.—*Geo. C. Bunker*.

**Glenmore Dam for Calgary Water Supply.** West. Constr. News & High. Bldr., 7: 10, 297–298, May 25, 1932. Two following units of improvements to Calgary, Alberta, Canada, water system have been completed. (1) Glenmore dam, on Elbow river, concrete gravity structure, 1050 feet long on crest and 60 feet high from streambed to crest, creating impounding capacity of 3750 m.g. (Imperial). (2) Sub-structure of 27-m.g.d. (Imperial) purification plant.—*Geo. C. Bunker*.

**An Apparatus for the Continuous Recording of pH.** A. E. J. VICKERS. J. A. SUGDEN, and R. A. BELL. Chemistry and Industry, 51: 26, 545–554, June 24, 1932 and 27, 570–574, July 1, 1932. Apparatus comprises glass electrode, thermionic potentiometer, and either milliammeter, or ordinary Cambridge thread recorder. Potentiometer makes use of WHEATSTONE bridge principle, using pair of matched valves as resistances. Apparatus eliminates drift of zero, so marked in previous attempts to use thermionic valve.—*W. G. Carey*.

**An Electrode Boiler for Distilling Water.** ANON. Engineer, 153: 3977, 366, April 1, 1932. Illustrated description of electrode boiler, rated at 30 kilowatts, working on single phase supply at 200 volts with one pole earthed. Plant is controlled by time clock, which at set time closes circuit operating feed pump. Current passes when water reaches electrode level, and increases as water-level rises, until load previously set on patent control panel above boiler is reached, when electro-magnetic relay stops pump until water-level falling reduces load, when pump starts again.—*W. G. Carey*.

**Ancient and Modern Methods of Water Measurement.** F. C. LEA. Water and Water Engineering, 34: 404, 276–290, Midsummer 1932; read at Summer Meeting of Institution of Water Engineers, May 18, 1932. After mentioning importance of stream-gauging and of run-off measurements, author gives historical survey of methods of water measurement. Formulae for flow in pipes, or for measuring instruments of pipe, orifice, or weir, type should not be used without reference to dimensions and velocities. In experimental work, temperature should be recorded and also the values of coefficients as related to those quantities upon which, as indicated by theory of similarity, the coefficients must depend. In present state of knowledge, the weir is accurate only when used under specified conditions, for which accurate calibration curve has been obtained from direct volume measurements. Weirs should have no end contractions, should be made of a vertical plate with no projections, and both weir and channel should be protected from wind. Weir channel should be as deep as possible, to diminish uncertainty due to velocity of approach, and

distribution of velocity should be as uniform as possible. Screens may be necessary; but these must not introduce oscillations, or sharp falls, in surface of water. Siphon spillways, Venturi meters, orifice diaphragms, Pitot tubes, and Venturi flumes are also dealt with. Flow can be checked by salt solution, salt content being determined either chemically, or electrically by copper cathodes connected with battery and galvanometer.—*W. G. Carey.*

**The Construction of Gunong Pulai Reservoir, Singapore.** J. S. JACKSON. Water and Water Engineering, 34: 404, 266–274, Midsummer 1932; read at summer meeting of Institution of Water Engineers, May 18, 1932. Water from Johore, on mainland, is conveyed by ¾-mile causeway to Singapore island. Catchment area is 1950 acres and capacity of reservoir, 1220 million gallons. Two streams are impounded; construction including main dam, weir, and tunnel, besides subsidiary dam and apron. Main dam is 470 feet long at road level, is curved in plan, and has hearting of concrete, downstream face being of random-squared, rock-faced, rubble masonry set in 2 to 1 cement mortar. Weir is 50 feet long with freeboard of 3 feet and maximum height of 14 feet above concrete apron and is provided with long concrete tail to prevent scouring of river bed in floods. Concrete apron is 100 feet long and is reinforced in centre with expanded metal. Subsidiary dam is 340 feet long, with maximum height from bed-rock of 30 feet, of which 25 feet are above ground; it is built with grooved construction joints, running from back to front. Detailed description of works and of plant is given, together with illustrations of workings.—*W. G. Carey.*

**Reinforced Concrete for Water-Retaining Structures.** H. C. RITCHIE. Water and Water Engineering, 34: 404, 250–262, Midsummer 1932; read at summer meeting of Institution of Water Engineers, May 18, 1932. Author deals with essentials of successful design; modular ratios; members in direct tension; members subject to bending; the case for T-beams; contraction stresses and joints; temperature stresses and expansion joints; essentials and improvements in construction; and impermeable concrete. Paper is illustrated with 12 figures.—*W. G. Carey.*

**Determination of Nitrates in Drinking Water.** W. MULDER. Pharm. Weekblad, 68: 995, 1931. From Water and Water Engineering, 34: 406, 380, July 20, 1932. To sample (containing about 0.0001 grams of nitrate) are added 5 drops 2 per cent sodium chloride and 1 cc. 0.5 per cent sodium salicylate and, after evaporation to dryness on water bath, 1 cc. sulphuric acid. After 10 minutes, mixture is washed into colorimeter tube with 10 cc. ammonia. Color is compared with standard containing 0.0001 gram nitrate treated with sodium chloride etc., as above. Accurate results are obtained in presence of from 0.00001 to 0.0001 gram nitrite, but larger quantities will cause high results.—*W. G. Carey.*

**A Simple Apparatus for Detecting Sporadic Colon Bacilli in Water.** H. HOCK. Zeitschrift für Hygiene und Infektionskrankheit., 112: 715, 1931. Layer of kieselguhr is deposited from suspension on surface of filter plate of

Berkefeld filter-candle material. Container for filter plate is attached to water tap to act as pressure, or suction, filter. When sufficient quantity of water under examination has passed through, kieselguhr layer is removed. Experiments showed that some 67 per cent of *B. coli* were retained on kieselguhr. Apparatus is recommended for simplifying water works procedure and could be used for *B. typhosus*.—*W. G. Carey.*

**Bacteriological Examination of Water.** J. M. Beattie. British Waterworks Official Circular, **14:** 98, 54–57. In article reprinted from "The Lancet" author says that aim of bacteriological examination should be to determine not only the presence of fecal pollution, but also its amount, since organic impurities present favorable nutrient medium for bacterial flora. For many years, of water-borne diseases, typhoid fever was of most consequence, but more recently paratyphoid fevers have taken its place. Dysentery, particularly the bacillary form, has been much more common within last few years, and some food-poisoning organisms, e.g., Gaertner's bacillus, have been found in water. Food-poisoning organisms are not uncommon in mice, birds, etc. and may find entrance in this way. In tap samples *B. coli* in 10, 20, or 40 cc., if confirmed by other samples, should condemn; in deep well, or spring, water, *B. coli* should be absent in 80 to 100 cc. and bacterial count on agar at 37°C. should not exceed 10 to 20 per cc.; while in upland surface water, *B. coli* should be absent in 40 to 60 cc. in average of three or four samples and agar count should not exceed 10 to 30 per cc. Regular and very thorough bacteriological examination of water supplies is essential, and interpretation of results calls for special care and experience.—*W. G. Carey.*

**The Influence of Copper on the Rusting of Copper Steel in the Atmosphere and in Different Waters.** Carius C. and Schulz, E. H. Mitt. Forsch.-Inst., Vereinigte Stahlwerke A.-G. Dortmund, **1929**, 1, 177; Chem. Zbl., **1930, 1,** 1044. Addition of copper in steel does not diminish its corrosive tendency, but protection from corrosion appears to follow from formation of protective coating. In atmosphere, copper oxide incrustation is formed, thick enough to account for the 50 per cent longer life of steel. In river, or artificial sea, water there is first precipitation of copper sludge and then formation of green hydroxide layer of low permeability by water. Presence of chloride ions affects formation of this layer and there is an optimum chloride concentration, depending upon certain colloidal chemical reactions. From investigation of course of reaction during corrosion, conclusions are drawn as to conditions for successful application of copper steel.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**The Phenomenon of Coagulation. Influence of Hydrogen-Ion Concentration on the Separation of Casein by Electrolytes.** La Rotonda, C. Ann. Chim. applicata, 1929, 19: 310; Chem. Abst. (U. S.), 1930, 24: 540. Study was made of action on coagulation of casein of nitric, hydrochloric, sulphuric, oxalic, tartaric, lactic and acetic acids, and of salt solutions. Casein does not appear to coagulate at pH of 4.7 to 4.6, which is usually given as its isoelectric point.

The nature of acid has more influence than pH value.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Investigations on the Sedimentation of Suspensions of Clay.** Boutaric, A., and Roy, M. Comptes Rendus, 1930, 190: 272. Results of experiments carried out by authors on rate of sedimentation of suspensions of clay in water confirmed those of Dubrisay. Authors deal with various points in completion of previously published results and outline experiments which prove that (1) assuming that at any time rate of fall is inversely proportional to viscosity of suspension, calculated according to Einstein's formula, then course of sedimentation can be represented as function of the time; (2) for similar media, sedimentation curves depend only on concentration of kaolin; (3) for suspensions of different concentrations, the initial rates vary as function of concentration, according to a hyperbolic law; (4) rate of fall decreases as rate of suspension increases. The effect of small quantities of capillary-active substances on sedimentation is discussed. Description and table of results are given of experiments on effects of camphor, menthol, and isoamyl alcohol on sedimentation of suspensions of kaolin. Although the capillary-active substances produced considerable decrease of surface tension, they did not accelerate the rate of sedimentation, but seemed to produce a very slight retardation in formation of deposit.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Perth Water Supply.** Parr, J. Trans. Inst. Eng., Australia, 1927: 8, 363. Deals with artesian supply, ground water supply, and supply from large catchment areas in hills of Perth Metropolitan Water Supply Area. Nature of area, early water supplies, population, and future water requirements are discussed. Details are given of pumping plants, reservoirs, and service system. Treatment of water by de-aeration and lime to prevent and reduce corrosion and purity of the water are considered. Diagrams, charts, and tables of data are included.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Rapid Sand Filtration at Durban Municipal Water Works.** Russell, A. W. So. African So. Civ. Eng., 1929: 140; Eng. Abst., 1930: New Series, No. 42, 203. Description is given of plant dealing with 10 million gallons of water per day, drawn from Shongweri Reservoir. Alum solution is fed to raw water in measuring chambers at rates varying from 0.25 to 4 grains per gallon for turbidities running from 70 to 200 p.p.m. Retention period of 90 minutes is provided in sedimentation tanks. Removal of bacteria is 91 per cent in coagulation, 8 per cent in filtration, and 1 per cent in chlorination. Details are given of filter beds, of media and of operation. Chlorine is admitted to absorption tower at pressure of 10 pounds per quare inch, dose of 0.25 to 0.5 p.p.m. leaving sufficient excess for destruction of bacteria. Typical "draw-off analysis sheet" is given which shows that turbidity was reduced from 85 to

0.7, and suspended solids from 38 to 0.7 p.p.m.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Process for Purifying and Decolorising Liquids.** MUCHKA, J. Austrian P. 114,879; Chem. Zbl. 1930: 1, 1342. Process for purifying and decolorising liquids is outlined. Liquid is treated with granular adsorption agent, such as decolorising carbon, activated silicic acid, etc., in apparatus similar to sand filter, with device for rearranging and, if necessary, regenerating adsorption agent. Rearrangement device consists of jet nozzle and pipe. The spent carbon can be regenerated by chlorinated water.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Removal of Iron from Water by Aeration.** BAMBERG, F. G. P. 458,874; Chem. and Indust., 1930, 49: B. 266. Iron is removed from water by aërating latter under pressure in closed vessel, and filtering through an open filter.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Portable Apparatus for Water Sterilisation.** MUCHKA, J. F. P. 671, 746; Chem. Zbl., 1930: 1, 1669. Portable apparatus for water sterilisation by continuous chlorine treatment and precipitation of organic matter. Last portion of chlorine is brought into action by depolarisation. Diagram of apparatus and description of process are given.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Apparatus for Dissolving Gases in Liquids, Especially for the Preparation of Chlorine Water.** BRAAM, G. Dutch P. 17,747; Chem. and Indust., 1930, 49: B. 270. Chlorine pressure forces water from absorption apparatus into upper reservoir from which it automatically falls back into absorption vessel, where it is agitated by automatic stirring device.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**The Treatment of Water and Waste Water with Chlorine and Copper and Chlorine and Silver.** ORNSTEIN, G., and KROKE, R. Gesund. Ing., 1930, 53: 153. Apparatus is described and illustrated for simultaneous addition to water of chlorine and either copper, or silver. Chlorine gas passes from cylinder through control system to vessel where it is dissolved in small quantity of water. Solution can be divided as required, part passing directly to water to be treated, while part is made to pass first through another vessel containing silver, or copper, waste, and carry some of this in solution to the water. Experiments are described on treatment with chlorine and copper of water for use in cellulose factory and of effluent from paper factory. In first case, water was drawn from river so much polluted with trade wastes that neither chlorine, nor copper sulphate, sufficed to control growth of fungus and

algae. Combined treatment with 2.5 p.p.m. of chlorine and 0.18 p.p.m. of copper was entirely successful. Intermittent treatment of clarified effluent from paper factory was successful in preventing fungus growths in stream. Chlorine and silver combination was tested on river water with very high content of bacteria and of suspended matter. Tests were made of raw water and of water after (*a*) chlorine alone and (*b*) silver and chlorine had been added on suction side of pump drawing from well. Results of bacterial counts and colititers are given in tables. Initial dosages of silver were too small to increase effect of chlorine; but on raising dosage of silver, or on adding ammonia, chlorine effect was increased. Suspended matter exercised retarding effect; when water was filtered, sterilization took place much more quickly.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Process for the Filtration of Potable Water. L'Ultrafiltre Septina.** F. P. 672,744; Chem. Zbl., **1930:** 1, 1668. Processes for filtration of drinking water which does not necessitate frequent renewal of filter material. Filter material is covered with layer of metallic hydroxide, for example, of manganese, zinc, or silver; or with layer of colloidal silver. This layer kills bacteria, etc., thus preventing them from living on filter bed, decomposing, and giving rise to unpleasant taste in water.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Marble Tube Filter for Use in Water Supply Systems for Fixing Free Active Carbon Dioxide.** Ritschel, O. G.P. 458,510; Chem. and Indust., 1930, **49:** **B.,** 266. Free active carbon dioxide present in water supply is fixed by passing water through several narrow, vertical, sinous tubes filled with marble, solid sodium silicate, etc.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Filtering Liquids.** Pennell, R. H. L., and Wylie, A. W. B.P. 325,937; Ill. Off. J. Patents, **1930:** No. 2153, 1064. Accelerated reverse flow of liquid, for cleansing filters in which filtration occurs upward through bed of material, is obtained either by air, automatically stored under pressure above the bed during filtration, or by suction created by extending wash-water outlet for substantial distance below filter. Closed filter in which air is stored automatically and open filter with outlet extending for substantial depth below filter are briefly described. Diagrams of both filters are included.—*M. H. Coblentz* (*Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature*).

**Public Utility Securities.** V. Bernard Siems. Water Works Eng., **85:** 9, 5, 7, May 4, 1932. Continued restriction of bank credit presents almost insurmountable obstacle to obtaining loans secured by collateral. Need for ready cash has forced investors to sell good securities much below value. Federal relief is not extended to small enterprises which constitute backbone

of country's economic structure. The corporation must prepare itself to help its investors, either by advancing reasonable loans on their holdings, or by acquiring them at mutually acceptable price. States should pass laws allowing corporations to build up such stabilizing funds. This could be done best by straight and unqualified rate increase, or other method, whereby consumer would get refund after stabilizing fund had been established.—*Lewis V. Carpenter*.

**Clarksville, Tenn., Plant Improved.** C. N. Harrub. Water Works Eng., 85: 9, 595, May 4, 1932. Cumberland River is source of supply. Failure of old plant to produce good water was due to inadequate mixing of chemicals, low wash water rates, and plugging of laterals with sand. Filters were overhauled and new laterals placed. Rate controllers, loss of head gauges, larger wash water pump, duplicate chemical dry-feed machines, and an Aer-O-Mix were installed. In crowded pipe gallery, each effluent pipe was doubled back on itself and straddled with rate controller. Admirable water is now produced.—*Lewis V. Carpenter*.

**Progress in Quality of Water.** Jack J. Hinman, Jr. Water Works Eng., 85: 9, 505, May 4, 1932. Sand filtration introduced by Simpson in 1829. Law passed in 1852 that all London water be filtered. Untreated surface water generally used fifty years ago. St. Louis built sedimentation basin in 1866. Scientific anti-pollution programs are now being conducted. Chlorination of drinking water is now almost universal. Sand filters of original slow-sand type were found practically useless for muddy waters of Middle West, where turbidity often exceeds 7,000 p.p.m. Many ingenious methods were tried, infiltration galleries being most often used. These failed in most cases due to decreased flow. Des Moines, however, still uses them. Rapid sand filters seem to have originated in New Jersey during decade 1880–1889, and proved admirably adapted to muddy middle-western waters: development was most rapid during decade 1890–1899. Coagulant was first added just before water entered filter: it is now added prior to extensive mixing and sedimentation basins. Bacterial removal has become almost perfect. Attempts to remove color, tastes, and odors are now attended with high degree of success. Palatability, as well as safety is being striven for. Pollution of streams by municipal and industrial wastes is becoming a vital factor. Plants treating turbid water can handle heavier bacterial loads than similarly equipped plants treating clear waters. Table is given showing permissible maxima of colon group organisms in untreated water which various types of treatment plants can safely handle. Sewage has been treated to meet U. S. Treasury Standards for drinking water. Animal parasites may exist in water that is bacteriologically pure. The future plant operator will probably consider our methods crude.—*Lewis V. Carpenter*.

**Cuban Water System.** George W. Biggs. Water Works Eng., 85: 9, 509, May 4, 1932. American Water Works and Electric Company purchased two Cuban-owned and -operated water utilities in 1929. They furnish water for Marianao, Reglo, and six smaller communities. Two separate pumping sta-

tions, about 2,000 feet apart, draw their supply from Almendares River, which is spring fed and, except in rainy season, when turbidity may reach 5,000 p.p.m., clear. At each station, water enters under-ground coagulation basin by gravity and is pumped thence through pressure filters into distribution system. Four elevated concrete tanks furnish storage and equalize pressure. Sanitary law requires only 5½ pounds pressure, individuals pumping to private elevated tanks. New company carries 40 pounds pressure. Former rates were based on rental value of property. Properties paying rent from $1 to $10 a month pay $1 per month for water service for each service connection; rentals of $10 to $20, $1.50 per month; of $20 to $32, $2 per month; of over $32, $3 per month. Grocery stores, cafés, barber shops, etc. pay double this amount. Capacity of each service connection is limited to flow through hole 6 mm. [0.236 inch] in diameter drilled through plug on curb cock. Company got permission to offer consumer choice of old flat rate or of metered rate. Notwithstanding that metered rate would prove cheaper to most consumers, only 4 or 5 chose metered service. Consumption is at rate of 124 gallons per capita per day and is practically the same between 2 and 4 a.m. as at other times, proving that much waste occurs. As most buildings are fire-proof, fire protection receives little thought. Laws require absence of gas formers in 1 ml. Because of pressure filters, chlorine is added at coagulation basin. High pressure feed chlorinators are being installed. Differences in laws, customs, and language do not greatly hamper operation.—*Lewis V. Carpenter.*

**A Utopian Water Department.** James E. Gibson. Water Works Eng., 85: 9, 513, May 4, 1932. Supply must be ample for domestic and manufacturing use and for fire protection, sanitarily irreproachable, adequate to remove all wastes, relatively low in cost, and readily available for proper distribution. Operation and management should be entrusted to commission free from politics, who would appoint their own officers. Financing should be by issue either of short term serial notes, or of long term loans, or bonds, approved by State Utilities Commission and voted upon by qualified free-holders owning at least 50 percent in value of total real property. Not more than 80 percent of actual cost of improvements or extensions should be financed by fresh issue of capital: remaining 20 percent should be paid for out of net operating surplus. Comprehensive scheme of development should be planned and followed. Rate schedules should be strictly uniform for all customers alike. Pension fund should be carried as operating expense. Accounting, collections, and disbursements should be handled by treasurer, selected by Commission, but under supervision by chief executive of Commission, who would be responsible for operation of plant. Personnel should include engineering, operating, and accounting departments. Property should be protected by proper insurance.—*Lewis V. Carpenter.*

**The Water We Drink.** Caleb Mills Saville. Water Works Eng., I. 85: 9, 579, May 4, 1932. Average consumer pays little attention to water supply unless things go wrong. People prefer water from pure sources. Drought and economic depression affect water supply work. Water works must be prepared to cope successfully with either of these emergencies. Sev-

eral successive years of relatively low precipitation may cause more damage than one very dry year between years of high precipitation. Droughts can be provided against by making water works systems adequate. Opportune time to urge improvements and developments is immediately after depression period, when money is becoming more easy to obtain. Lengthy rainfall records are very important in predicting future supply: data for several watersheds are given. Diagram showing population and consumption statistics for Hartford for period 1906–1930 is included. In another diagram, water rates in several northeast cities are compared and domestic, intermediate, and manufacturing rates separately shown. **II.** **85**: 10, 639, May 18, 1932. Cities are now seeking pure water at long distances rather than use near-by polluted sources. During drought, treated river water, although meeting U. S. Treasury Standards, caused vomiting and diarrhea. Low water forms ideal breeding place for algae growths which, in turn, impart taste and odor to the water. **III.** **85**: 11, 690, June 1, 1932. Provision must be made against periods of drought. It may be advisable to have two systems, one for domestic use and one for manufacturing and fire protection. Parks and hunting reserves are encroaching upon water gathering grounds. Pure and safe water for all is more important than attractive water and forests for a few. Per capita consumption increases with population and with education. Actual consumption for fire fighting is but a nominal amount. It is cheaper to spend large sums for good water than to pay for damages caused by sickness. Polluted source should be used only as a last resort, even if adequate purification processes can be installed and tapping of pure source be much more costly. Water gathering grounds should be rigorously patrolled. Superior advertising value of a pure, as compared with a polluted, source is often over-looked.—*Lewis V. Carpenter.*

**The New Waterworks at Mannheim, Germany.** PICHLER. Gas- u. Wasserfach, **73**: 621–7, 651–5, 1930. From Chem. Abst., **24**: 4564, September 20, 1930.—*R. E. Thompson.*

**Seasonal Variation of Silica in Takasukanuma, Saitama.** S. YOSHIMURA. Japan J. Geol., **7**: 101–13, 1930. From Chem. Abst., **24**: 4565, September 20, 1930. Description of seasonal variation in silica content of water of small Japanese pond.—*R. E. Thompson.*

**Active Oxygen as a Rust Preventive.** HANS HEBBERLING. Farben-Ztg., **35**: 1256–7, 1930. From Chem. Abst., **24**: 4646, September 20, 1930. "Active oxygen" theory of rust prevention alone cannot account for superiority of red lead as rust preventive. Impermeable soaps formed in paints containing it are also an important factor. Zinc chromate with greater percentage of oxygen than red lead forms less soaps and consequently is not as good as red lead. Among different samples of red lead, degree of dispersion is also a factor.—*R. E. Thompson.*

**The Temperature Factor in Water Supervision.** A. GUILLERD. Tech. sanit. munic., **25**: 108–11, 126–32, 1930. From Chem. Abst., **24**: 4877, October

10, 1930. Temperature is of great importance in keeping check on water supply, especially in case of mineral and ground waters. Latter usually remain at same temperature, within very narrow limits, and any variation indicates dilution, or seepage, etc., of waters from other water tables, or even of surface waters. Temperature should be taken regularly over period of years to be of greatest value. In some cases there is well defined correlation between temperature and fecal pollution.—*R. E. Thompson.*

**Utilization of Noxious Waters by Means of Regulated Lakes. The Seine Basin.** HENRI CHABAL. Tech. sanit. munic., **24**: 363–7, 1929. From Chem. Abst., **24**: 4879, October 10, 1930. Use of artificial reservoirs for sedimentation and purification of impure waters, especially from rivers, is recommended.—*R. E. Thompson.*

**Gravimetric Analysis with the Kuhlmann Microbalance. I. Drying of Precipitates. II. Determination of Aluminum.** A. PICHLER. Mikrochemie (Festschrift), **1929**: 6–13; Analyst, **55**: 298–9. From Chem. Abst., **24**: 4726, October 10, 1930. **I.** Simple apparatus for rapid drying of precipitates in dust-free stream of air, or other gas, is described. It consists of glass tube (diameter about 2.5 centimeters) drawn out at one end. Passing through narrow end is narrower tube connected with suction pump. At wide end is an air-filter. Tube fits in an aluminum drying block of PREGL type. Apparatus is designed for determinations with EMICH's microfilter tubes and microbeakers, in which precipitate is weighed together with filter tube and beaker (6 to 10 cc. capacity). Beaker containing precipitate and microfilter tube is placed inside the drying tube and filter stem is attached, with valve tubing, to tube connected with pump. Thus air at required temperature can be passed down beaker and through filter tube. **II.** Aluminum is determined by weighing as the complex salt with 8-hydroxyquinoline, which contains 5.87 percent aluminum. Reagents: (*a*) The "oxin reagent" is made from 5 grams of oxin, 12 grams acetic acid, and 85 grams water. Mixture forms a solution after gentle warming for some time. (b) Twice normal ammonium acetate. Procedure: from 6 to 8 milligrams of, e.g., potassium alum, are weighed into microbeaker, dissolved in about 1 cc. of water, and 1 drop of hydrochloric acid and 0.3 cc. of oxin reagent are added. Mixture is heated over boiling water bath and acetate solution added drop by drop until first sign of permanent precipitate. After 1 minute the precipitate becomes crystalline, at which point an additional 0.4 cc. acetate solution is added, dropwise. For more than 1 milligram aluminum oxide the amount of reagents should be proportionately increased. Solution is filtered hot through microfilter, the crystals are dried as completely as possible by suction, and washed 4 or 5 times with from 0.25 to 0.5 cc. of hot water. Filtration and washing take about 5 minutes. Filter tube and beaker are then dried for 5 minutes at 140° in current of air, using apparatus described above. Filter tube and beaker are cooled and weighed by usual procedure (EMICH, Mikrochem. Praktikum, 1924, 63; Lehrbuch der Mikrochemie, 2nd. edition, 1926, 84). Typical results showed following percentages of aluminum oxide: 10.74, 10.77, 10.73, 10.81, and 10.82; theoretical 10.77. Procedure for macro-estimation of aluminum by same method is described. Iron is also quantita-

tively precipitated by oxin. When both are present, the sum may be found and iron determined separately by titration. This procedure can be employed only if amount of iron is low compared with amount of aluminum, as the iron precipitate filters poorly.—*R. E. Thompson.*

**Fractures in Boiler Metal.** A. E. White and R. Schneidewind. Trans. Am. Soc. Mech. Eng. (advance copy), June 9–12, 1930, 19 pp. From Chem. Abst., 24: 4743, October 10, 1930. Examinations, largely metallographic, have led to some generalizations and to classification of cracks and fractures as related to causes of failures. Types of failure and their metallographic characteristics are discussed. Material presented consists of short review of literature on boiler-metal failures, detailed descriptions of fractures in boiler metal due to known causes, and descriptions of actual failures in service.—*R. E. Thompson.*

**The Suitability of Boiler Feed Waters.** Nalini and Michelucci. Rivista tec. ferrovie ital., 37: 60–79, 1930. From Chem. Abst., 24: 4879, October 10, 1930. Behaviour of several boiler feed waters is discussed and methods of correcting alkaline waters described. Specifications are suggested for locomotive waters for Italian railroads.—*R. E. Thompson.*

**Salt Content of Feed Water.** R. Klein. Wärme, 53: 377–82, 1930. From Chem. Abst., 24: 4879, October 10, 1930. Influence of salt content on brine deposit on boiler is discussed. Four processes of softening carbonate- and sulfate-rich water are described. Brine and heat losses occurring herewith are studied and examples are cited.—*R. E. Thompson.*

**Metallurgy of Arc Welding.** W. Zimm. Elektroschweissung, 1930: 4, 65–71. From Chem. Abst., 24: 4751, October 10, 1930.—*R. E. Thompson.*

**Chemical Industry Uses Gas Welding.** R. C. Hosterman. Acetylene J., 31: 491–6, 1930. From Chem. Abst., 24: 4751, October 10, 1930. Discussion of application of oxy-acetylene welding to pipe racks, pipe assemblies, tanks, etc. Welded-tank plans and details of welded joints are given. *R. E. Thompson.*

**Building an All-Welded Oil-Storage Tank by Arc Welding.** I. S. Dmitrie. J. Am. Welding Soc., 9: 5, 64–70, 1930. From Chem. Abst., 24: 4751, October 10, 1930.—*R. E. Thompson.*

**Study of the Electric Welding Arc with Iron Electrodes.** G. M. Tikhodeev. Elektrichestvo (Moscow), 1930: 4, 196–203. From Chem. Abst., 24: 4751, October 10, 1930.—*R. E. Thompson.*

**Notes on Corrosion of Iron and Steel.** S. G. Sastry. Bull. Mysore Eng. Assoc., 7: 4, 15–20, 1930. From Chem. Abst., 24: 4751, October 10, 1930. Practical interest in this problem at present time in Mysore lies in direction of relative corrosion of steel and cast iron when employed in form of pipes for

carrying water. Influence of dissolved substances on corrosion and colloid theory of corrosion are discussed.—*R. E. Thompson.*

**Asphalt Coating to Protect Pipe Line from Corrosion.** J. Logan. Oil Weekly, 57: 1, 32, 36, 1930. From Chem. Abst., 24: 4751, October 10, 1930. Asphalt coatings are being used by Houston Pipe Line Company in marshy ground that is conducive to excessive corrosion. In spite of relatively high cost, work is regarded as economical, since it not only eliminates expense of replacing pipe, but also prevents interference with continuous seervice of the line.—*R. E. Thompson.*

**New Method for the Measurement of the Absolute and Relative Corrosion of Metals.** G. Gollnow. Chimie & industrie, 23: 1359–60, 1930; cf. C. A., 24: 2412. From Chem. Abst., 24: 4750, October 10, 1930. Brief description of Tödt's method (C. A., 23: 1859, 5146) and its advantages.—*R. E. Thompson.*

**Water Service in Swedish Villages.** John Bergstroem. L'eau, 23: 10–1, 1930. From Chem. Abst., 24: 4877, October 10, 1930. Water service is supplied in 112 villages; largely from surface sources, although a few ground waters are utilized. Ground waters are often highly ferruginous, but not high enough in manganese to cause trouble. Chloride content is low. Iron is removed by aëration and filtration. Owing to high color of surface waters, slow filtration is usually resorted to, although recent rapid filtration units, with alum as coagulant, have given very satisfactory results.—*R. E. Thompson.*

**The Removal of Troublesome Substances in Drinking Water. II.** F. Sartorius and W. Ottemeyer. Gesundh.-Ing., 53: 227–34, 1930; cf. C. A., 23: 4985. From Chem. Abst., 24: 4879, October 10, 1930. The ability of several brands of charcoal to remove foreign substances from water filtered through them was studied. Curves are given showing the amount of chlorine, phenol, trichlorophenol, hydrogen sulfide, and organic dyes adsorbed from water. Dyes, hydrogen sulfide, and chlorine were adsorbed well. Phenols and chlorophenols were not removed to same extent as the other compounds studied. Use of charcoal for adsorbing undesirable constituents from water is recommended.—*R. E. Thompson.*

**Oxygen Analysis in the Boiler Room.** M. E. Fitze. Power 72: 136–9, 1930. From Chem. Abst., 24: 4961, October 20, 1930. Details are given for convenient set-up and operation of Winkler apparatus.—*R. E. Thompson.*

**A Note on the Use of Crystal Violet in Presumptive Tests for Water Pollution.** C. N. Stark and C. W. England. Jour. Bact., 23: 36, 1932. When Salle crystal violet broth was tested with *B. coli* from feces, 35 percent of samples tested gave negative results, although standard broth gave 100 percent as positive. Authors question value of this medium for water testing.—*Edw. S. Hopkins (Courtesy Chem. Abst.).*

**Two Rapid Methods for Distinguishing Between B. Coli and B. Aërogenes.** GLEN A. LINDSEY and C. M. MECKLER. Jour. Bact. 23: 115, 1932. (1) Modification of WERKMAN method for VOGES-PROSKAUER test. Incubate at 37°C. in standard glucose broth for 24 hours and then test with alkali and ferric chloride as in original method. Results give close checks. (2) Reduction of aqueous solution of methylene blue. Add 1 drop of saturated solution to second lactose tube (completed test) and note if reduction occurs after standing one hour. Aërogenes reduces methylene blue under these conditions; colon does not. By using these tests, time required to distinguish between *B. coli* and *B. aërogenes* is reduced to one additional hour after 24-hour incubation without special media.—*Edw. S. Hopkins (Courtesy Chem. Abst.)*.

**The Selection of a Dilution Water for Bacteriological Examinations.** C. T. BUTTERFIELD. Jour. Bact., 23: 355, 1932. Distilled water has some bactericidal influence; its use as diluting medium for bacterial plating is open to question. Synthetic phosphate water, or buffer water known as formula C of MOHLMAN, SWOPE, and EDWARDS, gives best results. Sterilization should be done in resistance glass containers only, as material is dissolved from glass of poorer quality and from flint glass. Final pH of water after sterilization should not exceed 8.2 to give consistent results; pH value of 9.0 is partially bactericidal.—*Edw. S. Hopkins (Courtesy Chem. Abst.)*.

**Colon-Aërogenes Organisms in Well Waters.** FRED O. TONNEY and RALPH E. NOBLE. Jour. Bact., 23: 473, 1932. This study shows close relationship between *B. coli* count on differential medium and fecal contamination as shown by sanitary survey. *B. aërogenes* counts were associated with conditions classed as of doubtful contamination by survey, indicating possible potential danger.—*Edw. S. Hopkins (Courtesy Chem. Abst.)*.

**Average Bacterial Counts.** A. H. ROBERTSON. Jour. Bact., 23: 123, 1932. Mathematical discussion of relative merits of geometric and arithmetic means to express bacterial density. Author advocates adoption of geometric mean as preferable.—*Edw. S. Hopkins (Courtesy Chem. Abst.)*.

**Growth Rate of Individual Bacterial Cells.** C. D. KELLY and OTTO RAHN. Jour. Bact., 23: 147, 1932. Calculation of probable growth rate of organisms up to four generations.—*Edw. S. Hopkins (Courtesy Chem. Abst.)*.

**An Improved Reagent for the Acetyl-Methyl-Carbinol Test.** EINAR LEIFSON. Jour. Bact., 23: 353, 1932. Copper sulfate, to concentration of 0.1 percent, is added to regular 10 percent sodium hydroxide solution used for this test. Copper sulfate is dissolved in ammonia water and then added to hydroxide solution. Using this reagent, red coloration will appear in from 10 to 20 minutes.—*Edw. S. Hopkins (Courtesy Chem. Abst.)*.

**Behavior of Calcium Salts at Boiler Temperatures.** FREDERICK G. STRAUB. Ind. Eng. Chem., 24: 1174, October, 1932. Studies of reaction $CaSO_4 + Na_2CO_3 \rightleftharpoons CaCO_3 + Na_2SO_4$ were made at temperatures between 182°C. and

282°C. It was found that equilibrium ratio of carbonate to sulfate under boiler conditions was not exactly determinable from analysis at room temperature, because of differences due to temperature changes. Sulfate scale will not form at these temperatures if small amounts of carbonate and hydroxide alkalinity are present.—*Edw. S. Hopkins.*

Jour. New Eng. W. W. Assoc., June, 1931, 45: 2. **The New Gravity Water Supply System of Albany, N. Y.** ROBERT E. HORTON and BENJAMIN L. SMITH. 89–135. Albany's first water supply was from Renssalaer Lake in pine plains to northwest. In 1876, water was pumped from Hudson River at Quackenbush plant. Slow sand filtration, recommended by ALLEN HAZEN in 1897, proved inadequate and rapid sand plant which followed was taxed by high pollution load of Troy, Schenectady, and other communities, together with industrial wastes. Serious typhoid epidemic followed flooding of plant in March, 1913. Necessity for new source of water led to various surveys, until finally senior author recommended Hannacrois-Basic-Catskill Gravity Supply, with 100 percent metering to bring consumption below 20 m.g.d. Plan was to connect several sources with pipe conduit and run to new distributing reservoir on northerly side of city with flow line at el. 350, sufficiently high to supply the entire city by gravity under suitable conditions. Project will embrace 107.82 square miles of drainage area. Total estimated cost is $16,105,395, or $234,000 per m.g.d. for the three stages of the development. While use of two main reservoirs might have made filtration seem unnecessary, this requirement was imposed by New York State Water Power and Control Commission, who felt that it would be advisable until organic pollution was removed by flowage area. First stage, completed in spring of 1931 at cost of $9,000,000, includes dam on Basic Creek to impound 670 m.g., diversion tunnel to carry flow of Basic Creek to Hannacrois Creek, Alcove Dam at el. 625, 48-inch cast iron main, 105,000 feet long, from Alcove Dam to Loudonville Distribution system, rapid sand filtration plant, Loudonville Reservoir, capacity 100 m.g., and rearrangement of distribution system. Construction details include removal of existing graves from cemeteries to points more than 300 feet distant, in accordance with sanitary requirements; raising of town road above crest of Basic Creek dam; and crossing of three systems of railroad tracks between filter plant and Normanshill. In order to avoid expense of bridge over Alcove Reservoir, it was necessary to purchase 4050 acres of farm and timber lands, which would have been isolated from state road north of reservoir. Filter plant has normal capacity of 32 m.g.d., to be doubled by future development. Provision is made for aëration before filtration and for chlorination following. Lime will be added before water enters clear well, which is designed as sedimentation basin. The 48-inch supply conduit extends from clear well to city of Albany. Loudonville Reservoir is divided into two basins by center dyke and connected to existing 7-foot city storm water drain by 24-inch drain 3600 feet long which may be used for overflow purposes or for emptying of either basin. When three stages are completed, supply available, 69 m.g.d., will be sufficient to care for city at normal rate of growth until year 2000.

**Recent Developments in Chlorination.** FRANCIS D. WEST. 136–144. Writer traces development of chlorination from his own early experiments

using chloride of lime for pre-chlorination at Torresdale Filter Plant at Philadelphia in 1909, to the present. First theory on disinfecting action of chlorine, ascribing it to nascent oxygen evolved, was revised following work of Braidech, Mohlman, et. al., who proved direct toxicity. Third possibility has been suggested by Bunau-Varilla: namely that sodium hypochlorite in attacking organic matter gives off rays resembling X-rays, extending zone of destruction. In treating water supply of Rheims, 0.1 p.p.m. instead of 1 to 4 p.p.m. was used, with no taste and absolute antisepsis. **In discussion,** Enslow points out that other investigators have failed to verify these results. Johnson at Flint, Mich., in treating sewage found that distribution was all important in avoiding over and under chlorination. Prolonged antiseptic action of chlorine can apparently, when needed, be secured by increasingly practised use of ammonia. Since chlorination is most affective in alkaline solution, some waters require addition of caustic soda, or of soda-ash, before chlorination. With filtration, use of ammonia reduces chlorine dosage required. Records of plants studied show best results with chlorine: ammonia ratio of 3 to 2. Ornstein in Germany has demonstrated that chlorine as algaecide can be improved by addition of traces of copper. Dosage of 2.5 p.p.m. chlorine plus 0.18 p.p.m. copper has proven effective where 20 p.p.m. of chlorine alone and 100 p.p.m. of copper sulfate alone had failed. Pattilo and McMahan find that chlorine acts as catalyst in speeding up coagulation. Chlorine used ahead of hot-process lime-soda treatment prevents scale formation. There is still need for further study to determine how little, not how much, chlorine may be used to produce safe water at low cost, when it is thoroughly and properly mixed.

**The 1929–30 Drought in New England.** H. B. Kinnison. 145–163. Daily, or continuous, gaugings of rivers are obtained at about 120 regular stream-flow measuring stations in New England by Water Resources Branch of U. S. Geological Survey. Author discusses low levels following drought which affected not only New England, but also the South, the Central States, and Oregon on West Coast. Municipalities with impounded supplies experienced less difficulty than those dependent upon natural flow of rivers. Acute water shortage constrained in many cases resort to emergency supplies.

**Effect of the 1929–30 Drought upon the Water Supply of Rockport, Mass.** G. C. Houser. 164–167. This popular resort on Cape Ann has summer population of over 10,000, or treble the normal figure. Water supply is from Cape Pond, a natural body of water in southerly part of town. Drought of 1929–30 reduced by 53 percent quantity of water in storage in Cape Pond, despite use of tubular well as stand-by. Necessity for emergency supply from abandoned quarry, which was under consideration, did not arise.

**Practical Points in the Operation of Town Water Pumps.** Charles E. Green. 168–77. In discussing precautions necessary where electric-motor-driven centrifugal pumps cannot be placed below water level, author considers positive priming as of greatest importance. Pumps must start, and must not lose their prime while running. For dependable priming, priming pumps should have dual power. Suction pipes may be equipped with air chambers for automatic vacuum control, or priming may be controlled by float switches. To date, protective features have been little used, reliance being placed on

periodic inspections, or upon operator. Montclair system is cited as interesting example of automatic control through pressure-reducing valves in distribution system. From Wanaque Reservoir, water is pumped to low-pressure system, whence secondary pumps send it to high-pressure area and to storage tank. When secondary pumps are started without notifying main station, pressure-reducing valves open automatically to middle and low pressure areas and water is merely recirculated. It is important that check-valves should close quickly with flow in normal direction, or slowly, when flow is reversed, to avoid severe water-hammer. Check-valves may be electrically controlled, or operated by water pressure in direction of flow in system, or by any combination of these methods.

**Rebuilding No Town Reservoir Dam.** W. GUY CLASSON. 178–80. No Town reservoir, built by mill-owners of Leominster, Mass., in 1853 to equalize flow of Monoostock Brook, was acquired by City of Leominster in 1926. Interest of other owners was so settled, that in 20 years city will own reservoir outright. Reservoir, 237 acres in extent, has capacity of 681 m.g. and receives drainage of 5 square miles. Spillway, originally 18 feet, at west end, was increased by stages to 60 feet, but channel below was not widened and failed to take care of freshets. CHARLES W. SHERMAN recommended increasing channel to full width at once. Hardpan material excavated was used to surface downstream face of dam. A short section was lined with concrete; remainder, with steel piling, driven into hardpan, with top about a foot above ground level. Above this, concrete wall 3 feet high was built. Total cost was $26,499.72.

**Items in the Operation of New York City's Water-Supply System of Interest to the Superintendent.** WILLIAM W. BRUSH. 181–87. A veteran of water works field passes on methods and principles in practice in his own system, not because they are necessarily correct, but rather to provoke thought among others. Where possible, land on water-sheds is purchased and patrolled to reduce pollution. Reforestation is practiced, water supplies are chlorinated, and reservoirs are treated with copper sulfate. Aqueducts are not cleaned, as chlorine helps to remove growths. Sewers crossing aqueducts must be of cast iron pipe with lead joints cased in concrete envelope, or of steel pipe. Annual fee of $10 is charged for each crossing. Aeration is practiced on all water at Ashokan Reservoir and on two-thirds of water at Kensico. Except certain well supplies, all water is chlorinated at least once. Dosage varies from 0.5 to 6 pounds per m.g. Residual of 0.1 p.p.m. is carried, with no taste or odor. Double chlorination has been found most effective. Cast iron pipes are lined with cement coated over with coal tar, or asphalt, applied hot. Pipe specifications permit Universal and McWane to compete. Barrel thickness of Class B-AWWA is required. New mains are sterilized with chloride of lime, or liquid chlorine, and must be accepted before being put into service. Where soil will absorb water and where hydrants are not connected to sewers, hydrants are provided with hemispherical cast iron domes holding 2½ times the barrel content as a combination drain and support. Hydrants are inspected each fall by Fire Department. High-pressure fire service operated by water department will provide pressures of 125 pounds in Brooklyn and 150 pounds on Manhattan Island, with higher pressure when desired. In built up areas electricity is being substituted for steam in pumping stations.

**Wrought Iron.** JAMES ASTON. 188–98. Definition established by American Society for Testing Materials, is "ferrous material, aggregated from a solidifying mass of pasty particles of highly refined metallic iron, with which, without subsequent fusion, is incorporated a minute and uniformly distributed quantity of slag." Increased cost, due to hand puddling, has caused many to overlook obvious advantages of wrought iron over steel pipe for water works purposes, where strength, durability, and resistance to soil and water corrosion and erosion are desired. New methods in use at A. M. Byers Co. plant in Pittsburg District permit output of 18,000 tons monthly. In contrast to hand puddling, the steps are separated. Slag is added and excess squeezed out in powerful presses. Finished ball is 3 tons, as compared to from 200 to 300 pounds in hand process. The product is uniform, with no carbon streaks. In general it is comparable to hand made product, except that its low cost should open up new markets, possibly in water works field.—*T. F. Donahue.*

**Alum Feed for Papermill Waters.** RICHARD T. BARNES, JR. Paper Trade Jour., 90: 14, 25, 26, 27. Discusses value of alum addition to paper-mill water under correct control, and points out logic of determining alum feed by pH-alum curve. Soft New England Waters require alkali in addition to alum. Connecticut River Valley water is especially suitable for paper: but color becomes troublesome in fall and its removal important. Alum is chemical principally used, either with or without alkali. Discusses point of optimum flocculation with alum and range of effective pH values. Hard waters are disadvantageous in paper, owing to difficulty in holding engine size and obtaining paper formation. Small amounts of alum are wasted; as optimum pH is not reached and disturbing elements are not removed. Effectiveness of alum lies in ability of alumina floc to precipitate into settling sludge coloring matters and other impurities. Describes method for determining optimum alum dosage with laboratory equipment of average mill. Tables and curves given show relationship between alum feed and pH value. Experimental methods are described and results interpreted for different waters and alum dosages. Conclusion is that optimum alum dosage is that which causes maximum and most rapidly settling floc: importance of correct dosage is stressed and disadvantages of either insufficiency or excess are pointed out. Six charts and tables illustrate article.—*E. B. Besselievre.*

**Nashville Water Works Pumping Station, Filtration Plant, and Recent Installations.** Southern City, 7: 4, 12–14 and 16–17, October 1932. Nashville water works supplies population of 180,000, including 153,000 urban and balance suburban. Distribution system comprises 400 miles of mains and 36,000 service connections, all metered. Per capita consumption averages 107 gallons per day and total daily consumption averages 19,345 m.g. Source of supply is Cumberland River, with water-shed of 12,000 square miles and extreme low water flow of 400 m.g.d. Works comprise George River Pumping station and 42-m.g.d. filtration plant. Intake pipe, of 48-inch diameter and 1700 feet long, is of cast iron. After filtration, water is pumped through 20,000 feet of 36-inch main to 50-m.g. storage reservoir: duplicate 36-inch mains allow diversion direct to distribution system in emergencies. Pumping equipment

and considerations governing its selection are described. Revamping of old equipment was combined with installation of new types. Fluctuating river level causes head against low-lift pumps to vary over range of 50 feet. Duty tests and plant lay-out are described. Results are given of tests on Uni-flow engines and pumps, which indicate guarantee exceeded by 10 percent. Supplemental 20-m.g.d. plant designed by J. N. Chester Engrs. was built in 1931 at total cost of $750,000, including fully equiped bacteriological and chemical laboratory. Trained chemist and superintendent are in charge.—*E. B. Besselievre.*

**Fire Hose Couplings. Standardization.** Southern City, 7: 4, 18, October 1932. Southeastern Fire Underwriters and affiliated organizations are endeavouring to reduce to one uniform size 800 different sizes of hose-couplings now in use. Thirty-eight states are now using standard. Much loss has been due to inability of out-of-town fire companies to connect to local hydrants. Describes methods used in changing to standard size. Terre Haute changed 1246 hydrants in 104 hours with 2 men and Ford truck, at cost for each two-nozzle hydrant of 13.1 cents. Objections against standardization are outweighed by advantages. Reduction in insurance rates, applied in towns adopting standard couplings, will alone more than offset cost of changing.—*E. B. Besselievre.*

**Nepean Dam to be Completed.** Australian Munic. Journal, Vol. 12, 30, July 30, 1932. Government of Australia and Sydney Metropolitan District Board are to spend £200,000 to complete Nepean Dam, near Bargo. Two years work for 735 men will link dam into Metropolitan water supply. Plant and machinery left at site when work was suspended will be used.—*E. B. Besselievre.*

**Water Supply for the Paper Industry.** L. M. Booth. Water Works & Sewerage, 79: 160–62, 1932. Careful consideration should be given to water treatment in the paper industry. Suspended matter should be removed by screening, sedimentation, and coagulation with alum and, if necessary, sodium aluminate. For polluted waters, preliminary chlorination, or chloramine treatment, is effective. Adequate mixing of chemicals and water may be obtained by mechanical agitation, or by baffles. Settling basin design has important bearing upon condition of water. Less than 10 p.p.m. turbidity should be present in filter influent. Quality of water is directly responsible for quality of paper.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

**Water Supply for the Paper Industry.** L. M. Booth. Water Works & Sewerage, 79: 237–39, 1932. Importance of conservation of water and of methods of treatment in paper industry is discussed.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

**The Theory of the Air Lift Pump.** F. Pickert. Engineering, 134: 3468, 19–20, July 1, 1932. Concise presentation, based on author's experiments over many years, of some new points of view and of method by means of which it is

possible to analyze and calculate velocities of air and of water, losses, and efficiencies of air-lift pump.—*R. H. Oppermann.*

**Reinforced Concrete Steel Water Mains.** C. J. Desbaillets. Canadian Engineer, 62: 18, 19–20, May 3, 1932. Abstract of paper before Montreal branch of Engineering Institute. Pressure pipe between pumping station and reservoir in Montreal is 34-inch Bonna pipe, a steel welded pipe with double reinforced concrete lining. Steel used for reinforcement is of structural grade. Both cylinder and spiral reinforcement are designed to work under normal tension stresses of 11,500 pounds per square inch. Inside lining is placed centrifugally: mix is 1 part cement, $1\frac{3}{4}$ parts sand, and $1\frac{1}{4}$ parts stone. Water: cement ratio is selected to give 3500 pounds compression strength at 28 days. Outside concrete lining is placed by vibration method and is of same mix, with the exception that water: cement ratio is selected to give 4500 pounds. These pipes are enabled easily to sustain bending stresses and high pressures by help of steel tube and of double joint. Inside joint on steel tube is of bell and spigot type and outside joint of reinforced concrete is practically a duplication of section of pipe itself.—*R. H. Oppermann.*

## NEW BOOKS

**pH and Its Practical Applications.** Frank L. LaMotte, William R. Kenny, and Allen B. Reed. Baltimore: The Williams & Wilkins Company, 1932. 6 x 9 inches, cloth, 270 pp., illustrated, indexed. $3.50. With certain definite and, perhaps, unavoidable exceptions later referred to, this book goes far to justify the high claims made for it by its publishers. It is intended for "all not interested in the theoretical aspects of hydrogen-ion determination;" but even those who are so interested will find much in its pages to repay them. In particular, the numerous charts are ingeniously designed to convey with clearness a maximum of important information in a minimum of space. Readers get the benefit of much experience garnered in past decade by firm with which its authors are connected. Scope of the book is wide. It begins with excellent exposition of conventional theories of hydrogen-ion concentration, pH, and buffer action, based on dissociation theory of Arrhenius and law of mass action. Methods of pH determination are then reviewed, with chapter on sources of error. Rest of book deals well and fully, though not, of course, exhaustively, with practical applications. Successive chapters are devoted to Water Supply, Corrosion Problems, Sewage and Waste Disposal, Sugar Industry, Gelatin and Glue, Leather Manufacture, Textiles, Pulp and Paper, Food Industries, Cleaning Processes, Electro-deposition of Metals, General Industrial Chemistry, Bacteriology (with which are grouped Pathology and Titration Procedures), and Soils. Six pages of index follow. The defects of book, in common with some of its merits, follow naturally from connection of its authors with a commercial firm. Appliances of types marketed by the firm receive a prominence not accorded to those of its rivals. There is, moreover, a rather startling departure from accepted practice, namely the advocacy for use as indicators of certain substances, while withholding all information as to their composition. This innovation is likely to

be gravely deprecated by chemists and even, perhaps, by "practical" men who are not so unpractical as to have forgotten the old adage concerning "a pig in a poke." Apart from these defects, not unnatural under the circumstances, reviewer can warmly recommend the book to all who are interested. Printing and paper are of high excellence. Type chosen is large and clear. Typographical errors noted were few and obvious, mostly transpositions. In figure 6, on p. 22, the subscript 2 is accidentally omitted from formula for magnesium chloride.—*Frank Hannan.*

**Public Utility Regulation.** WILLIAM E. MOSHER and FINLA G. CRAWFORD. Harper and Brothers, 1933. A study of the scope and effectiveness of methods of regulating public utilities through public service commissions. It is a book of over 600 pages, of 34 chapters, a conclusion, bibliography, index of cases and decisions, and a book index. It is well printed on unglazed paper, which is readable without eye strain. The sentence structure is simple and the thoughts of the writers are straightforward and easily understandable.

Part 1 gives consideration to the character of a public utility and a review of various methods of regulation, including history, legal authority, personnel, etc., of utility commissions. An interesting discussion is given as to whether commissions should act to initiate control and regulation over the utilities, that is, to act as defenders of public interest or to sit and judge the merits of arguments presented by its own staff and the spokesmen of the utilities, that is, to act as judges in a court, or to take both positions.

Part 2 deals with the administrative policies and problems of the commission. Chapters are devoted to corporate organization and finance, accounting, depreciation, valuation, rate of return, rate structures for electric, gas, water, telephone and street railway utilities, holding companies and interstate problems. The authors discuss the reproduction cost new less depreciation theory of value and it is their opinion that the paragraph devoted to valuation in the famous Smythe vs. Ames case could be blotted out of the record to the promotion of better administrative and judicial treatment of utilities. After outlining the theories of cost of reproduction, of price levels, cost indices, rate regulation without valuation and prudent investigation, they incline to the latter as offering the most hope for the solution of the rate base problem. In the chapters devoted to holding companies, a number of illustrations of the difficulty of providing effective regulation are given. These, with proposed solutions, make interesting reading.

Part 3 is devoted to special problems, such as motor carrier operation, rural electrification, grade crossing elimination, public ownership and public relations.

A conclusion is drawn that the art of regulation has not advanced as fast as has the necessity for regulation. Private ownership of utilities is on trial at present more than it has been at any time during the past twenty-five years of systematic utility control. Unless there is more cordial coöperation between the private owners and regulatory bodies, in the opinion of the authors, the only alternative is public ownership and operation.

This book supplies valuable information, not only to public service commissions, but to utility operators in giving each group an insight into the

problems of the other. It is believed the book has been written more from the viewpoint of the former than of the latter. It should serve excellently as a "freshman bible" to inexperienced men recently appointed to regulatory commissions who must know quickly "what it is all about."—*G. J. Requardt.*

**Report of the Bavarian State Board for Water Supply (Bayerisches Landesamt für Wasserversorgung) for the Fifty Years, 1878–1928, with Progress Report for the Years 1927 and 1928.** R. OLDENBOURG, Munich, 1929. Reviewed in Gesund. Ing., 1930, 53, 207. Report portrays range of activity of Bavarian State Board for Water Supply since its creation in 1878 and accompanying statistical information clearly conveys conditions of water supply at beginning of 1928, when 58.2 percent of population were completely supplied with piped water, 28.5 percent, partly supplied, and 13.3 percent still without supplies. Second part of the report contains survey of years 1927 and 1928, report on use of ground water, descriptions of buildings and of plans generally adopted for intakes and for collecting and storing reservoirs.—*M. H. Coblentz (Courtesy of the Department of Scientific and Industrial Research, Water Pollution Research Board, Summary of Current Literature).*

**A New Method for Disinfecting Water with Silvered Sand.** S. V. MOISEEV. Experimental Institute for Water Supply and Sanitary Technic. Leningrad, 1932. The disinfecting properties of several varieties of silvered sand upon microörganisms commonly found in untreated drinking water have been studied. The suspended matter present in water greatly reduces the oligodynamic action of the silvered sand by reducing the effective area of contact. To prevent this, the water should be filtered or, where this is impossible, the silvered sand should be washed at frequent intervals. Observing this precaution, the author found that the bactericidal action of silvered sand was greater than that of 0.22 to 0.136 p.p.m. of chlorine. In its oligodynamic action and stability, the silvered sand prepared by the author was found to be superior to the varieties found on the market. The sand contains 0.3 percent of silver. The apparatus employed consisted essentially of a delivery tank connected by means of a rubber hose to a glass cylinder containing in its upper portion a layer of sand serving as filter and a layer of silvered sand in its lower portion. The water was passed through the cylinder at the rate of 3 liters per hour.—*J. E. Schmidt.*